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Seismology in St. Louis University

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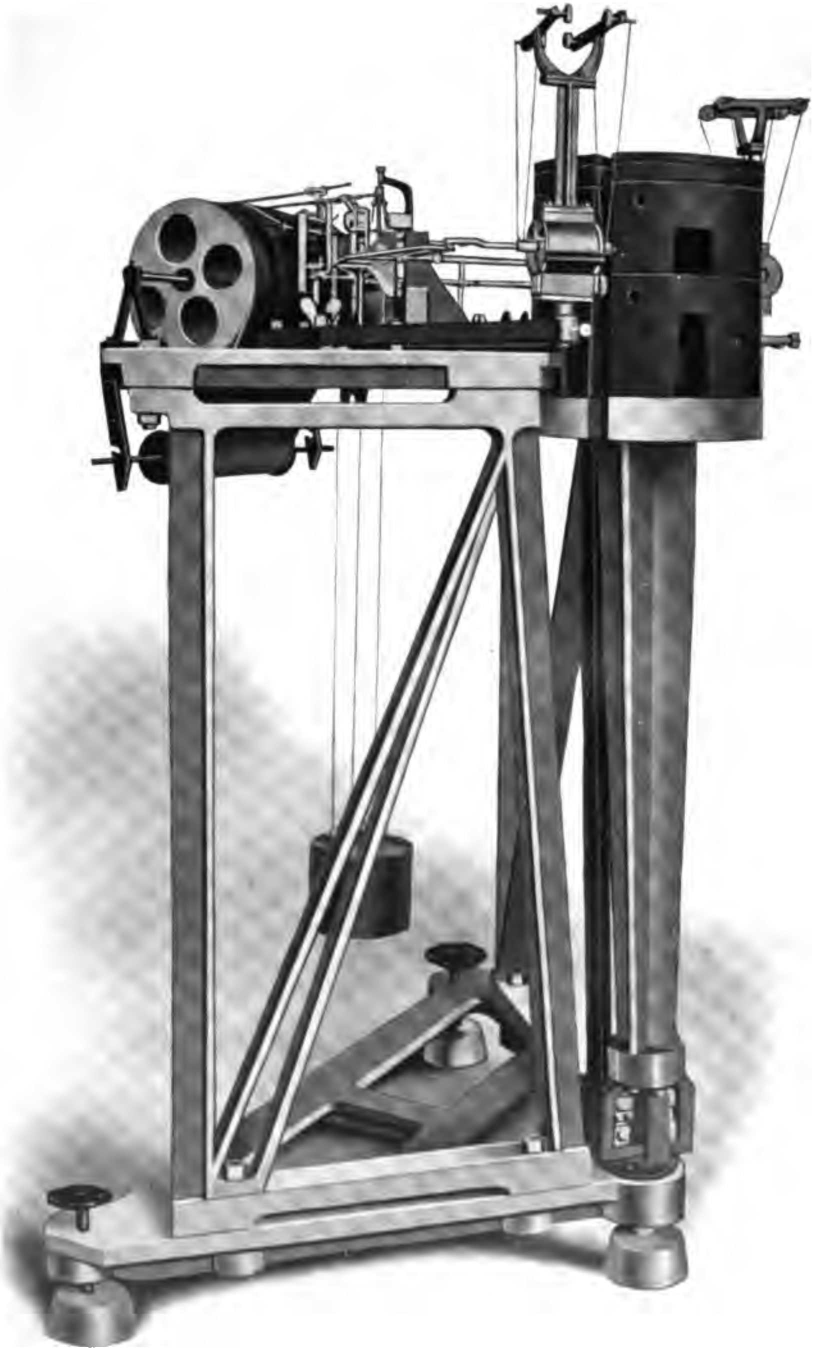

Wiechert 80kg. Horizontal Seismograph.

Seismology in St. Louis University

HISTORICAL OUTLINES.

THERE is perhaps no development in the broad fields of science, which has so completely captivated the attention of many of the keenest intellects of our age, and in so short a space of time, as the recent study of seismography. This new science opened so near the close of the last century, may justly be claimed by the present, twentieth century, as among its first excellent fruits. In a decade of years it has developed into gigantic proportions. Means and energy have not been spared in promoting it. Still, truly efficient work, as von Rebeur-Paschwitz pointed out in his able address to the Geographical Congress at London (1895), will be next to impossible until a complete chain of fully equipped seismological stations with a staff of reliable, interested, self-sacrificing observers will have been inaugurated in every part of the world. Dr. E. Wiechert, an acknowledged authority on seismology, voiced the same sentiments at the third International Conference for the Study of Seismology held at The Hague (1907). In every part of the world, "the gaps intervening between any two stations," he stated, "should be only 5000-6000 km." "This ideal," Dr. Hennig seems to think, "is at the present day still on the distant horizon."[1]

The urgent necessity was patent to all from the first. But recently, Prof. G. B. Rizzo, director of the Osservatorio di Messina, Istituto di Fisica Terrestre della R. Università, in his work *"Sulla Propagazione dei Movimenti Prodotti dal Terremoto di Messina del 28 Dicembre 1908,"* which was published only last January, laments that "the observatories were not a little more numerous, and these all equipped with instruments which would permit us to distinguish with certainty, in their diagrams, the various phases of the movements." In this way alone, will it become possible to follow seismic disturbances at small intervals, in their progress around the globe. For this purpose, the already extensive "International Seismological Association" was formed in Europe. Its first assembly was held at Strassburg just ten years ago, two years after the earnest appeal for the founding of an "International Seismological Association" had been made by Gerland

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[1] Dr. E. Hennig—*Erdbebenkunde.*

and his enthusiastic followers at the international "Geographical Congress" held at Berlin in 1899.

Strassburg was selected in 1903 by the "Second International Seismological Convention" to be the central bureau of the association, as it had already for several years enjoyed a like distinction among the Imperial German observatories. Prof. Dr. George Gerland, to whose able management was entrusted the important post of general director of the bureau, occupies the same position even at present.

The year 1907 witnessed another concourse of the world's learned seismologists. The "Third International Conference" included a representation which gathered from 22 States. At this period there existed 126 seismological observatories in different parts of the world, barring Japan. Germany possessed 15 in her own boundaries, and 3 in her dependencies. England and her colonies could boast of 60. "Milne" has become a household name among English seismologists, and must be identified with the rapid development of British seismology.

This brief sketch of the development of our science would, however, be sadly wanting in an essential feature, if we omitted to mention still a third nation, Japan, which deserves distinction not only as including within its borders the region of greatest seismicity, but for the active interest it has shown in the observation of seismic phenomena and that at a time when Europe was not yet awakened to its overwhelming importance. And it was her unique position that, as it were, forced Japan to take her bearings, and to accomplish what she has in the world of science. In 1880 a seismological association was formed. The results of its labors were issued in its own publications (Transactions and Seismological Journal). The University of Tokyo in the year 1886 incorporated a special department for the teaching of seismology under Prof. Sekiya, who was succeeded by Prof. Omori. Prof. Kikuchi makes mention of this with a spirit of honest pride when he says that "the chair of seismology in Japan is the only one of its kind in all the world." The famous earthquake of Mino-Owari in 1891 induced Prof. Kikuchi to establish a commission for the investigation of earthquakes (Shinsai Yobo Chosakwai or "Earthquake Investigation Committee"). An imperial edict of June 25th, 1892, signified the full approbation of the government in the establishment of the Committee. At the present day the country is literally covered with a network of over 1500 observing stations, of which number at least 70 are equipped with modern recording apparatus. Although much of prime importance, especially from the viewpoint of utility, was accomplished, the work was necessarily restricted. The narrow confines of the country impeded any great developments of scientific value, the like of which we have witnessed since seismology has become a study of such universal interest in the western world. With Japan, it must be admitted, it was a more immediate matter of physical self-protection.

Finally, the new science has found its way across the waters to our own land. There are, independently of the Jesuit Seismological Stations, some six or seven seismic observatories in the United States, mostly in the eastern States. About two years ago the United States joined the "International Association" and Mr. Harry Fielding Reid was appointed by the President as the representative for this country. Lately a Seismological Society of America has been organized with headquarters at Stanford University, Cal.

Rev. Fr. Algue, S. J., director of the Manila Observatory, in the Philippine Islands, suggested the question of the organization of a Jesuit Seismic Service, which was established five years afterwards. His interest in meteorology led Fr. Algue to confer with Rev. Fr. Odenbach, S. J., for many years director of the Meteorological Observatory of St. Ignatius College. The latter had made some more or less fruitful attempts at the observation of earthquake phenomena with machines of his own invention, as well as of the Omori type. It was mainly due to Father Algue's suggestion of spreading interest and calling out as many collaborators into the new field as possible, that Father Odenbach broached the great idea to his superiors with the petition for their approbation. At the same time he solicited their support towards the establishment of seismic instruments in all colleges under the control of members of the Society of Jesus in this country or at least in all such as already enjoyed the distinction of a meteorological observatory. These would doubtless be best fitted to lend a helping hand in the undertaking. Sixteen colleges, and among them St. Louis University, came thus to be equipped with seismological instruments of the Wiechert 80 kilogram type.

Fifteen stations are distributed through the United States as follows: Georgetown, D. C.; Brooklyn, N. Y.; Fordham, N. Y.; Worcester, Mass.; Buffalo, N. Y; Cleveland, O.; Mobile, Ala.; New Orleans, La.; Chicago, Ill.; Milwaukee, Wis.; St. Mary's, Kan.; Denver, Colo.; Santa Clara, Cal.; Spokane, Wash.; St. Louis, Mo. St. Boniface, Manitoba, in Canada, concludes the list of colleges which at this time installed seismic machines in America.

In other countries, too, the members of the Society of Jesus have given a practical proof of their devotion to seismology. It may be of interest to note that there are under the management of the Fathers of the Society the following meteorological observatories, many of which have already opened a department for seismological study, and all, no doubt, are looking forward to the day, when they, too, shall be enabled to subscribe their names to the daily increasing number of earnest and devoted seismologists: Bulawayo, Rhodesia; Stonyhurst, England; Cartuja (Granada), Spain; Madrid, Spain; Puebla, Mexico; Kalocsa (Pestmegye), Hungary; Gijon (Oviedo), Spain; Comillas (Santander), Spain; Galicia (Pontevedra), Spain; Tortosa (Tarragona), Spain; Orduña (Viscaya), Spain; Ambohidempona, (Tananarivo), Madagascar; Kildare, Ireland; Itù (Estado de S. Paulo), Brazil; Riverview, Sydney, Australia; Nova Friburgo (Estada de Rio Janeiro), Brazil; Cienfuegos, Cuba; Havana, Cuba; Manila, Philippine Islands; Calcutta (Bengal Presidency), East India; Specola Vaticana, Rome, Italy; Ksara (Beyrout), Syria; Zi-ka-wei, China; Boroma, Zambesi.

At the St. Louis University, the Department of Seismology was opened on October 22, 1909. On this day a seismograph of the Wiechert type (80 kilogram) was permanently erected in a vault under the administration building. The machine rests on a concrete pier 4 ft. x 4 ft. x 5.8 ft., constructed to be independent of the foundations of the buildings, and deep enough to eliminate the less violent disturbances. The pier stands on a few feet of loess underlain by Carboniferous, Silurian and Ordovician limestones, shales and sandstones, dipping toward the northeast. In an artesian well sunk somewhat less than four miles southwest of the university, the igneous substratum was reached at a depth of 986.08 metres below sea-level.

The effects of external changes in temperature and humidity are greatly restricted by two vestibules through which access is had to the instrument. They are separated by a doubly insulated wall with "refrigerator" door.

THE AIM OF OUR WORK.

The year's work has brought home to us the absolute necessity of accurate and systematic work. In this, as in other exact sciences, everything depends on reliable data and precise measurements. The data referred to are the records of earth motion propagated from centers of disturbance more or less distant. Since these vibratory movements are too faint to be directly perceptible, they can be studied only through the medium of a magnifying instrument. Such are the various types of seismographs. These instruments magnify the feeble tremors which pass through the earth beneath them, into measurable proportions, at the same time registering what has taken place.

If a mere catalogue of these phenomena and a rough estimate of their relative intensity were all that is desired, a sufficiently sensitive instrument would answer as equipment, and an examination and comparison of the daily records would be all the pains required. But the problems, with which the infant science of seismology finds itself confronted, will never have a satisfactory solution without a considerably greater outlay of painstaking labor. The most elementary of these problems is that of determining the velocity of transmission of seismic waves. Yet, little or nothing can be done towards its solution without (1) a recording instrument sensitive enough to register the beginning, at least, of the three chief phases; (2) means of ascertaining, to the minute and second, the times at which these were recorded.

Our station answers the first of these requirements in regard to a sufficiently large number of earthquakes, although in many of these instances the first preliminaries are missing or so indistinct that their beginning or initial impulse escapes recognition. As to the second requisite, we are sorry to say, that up to the present, it has not been realized fully. In no case could we be sure of the exact second, and often there was a doubtful margin of several seconds. Steps have been taken, however, to remedy this drawback.

This is one part of the task we have set ourselves. We are also trying to furnish our co-workers with a faithful record of the local disturbances registered. For a time we did this by reporting the maximum double displacements of the pen as recorded on the seismogram, i. e., the total amplitude $2a$, reckoned from turning point to turning point of the maximum vibration. This, it was thought, would be a reliable standard from which to judge of the effect produced at various stations by a given earthquake; but it was found unsatisfactory for several reasons: (1) It would have been necessary to have the various instruments of the network of stations concerned tuned, as it were, to the same pitch; that is, the constants on which the magnification depends, should be identical for all. Now, it was found impossible to fix the constants precisely at predetermined values and keep them unchanged for any length of time. (2) A more serious objection lies in the fact that there is no uniform correspondence between seismogram-amplitudes and those of the earth-tremors, except when the latter have a very short period compared with that of the instrument. In all other cases the magnification changes with the changing ratio of the two periods. Hence a large gram-amplitude is not necessarily indicative of a large earth displacement and vice versa. For these reasons it seemed advisable to change our method of reporting amplitudes. They are, therefore, now tabulated in our reports in terms of the earth amplitudes. This reduction of the recorded amplitudes to those of the earth motion entails a determination of the various constants of the instrument, which modify the magnification. After a brief description of the instrument and the working of the various parts we shall present, in concise form, the method we have found most practical for determining the value of the constants.

THE INSTRUMENT.

The seismograph consists essentially of a heavy mass poised on a stiff rod whose lower end terminates in a Cardanic hinge, which allows the mass to move freely in any horizontal direction. When the pier or support, on which the instrument rests, is set in motion by the tremblings of an earthquake, the Cardanic hinge and the frame of the machine, which rises to the level of the "stationary" mass, execute all the oscillations communicated to them, while the mass itself will tend to keep its position. It is the inertia of the mass which gives it stability, and hence the greater it can be made, consistently with the strength of the hinge, the better. Between the mass, which tends to remain stationary, and the frame which is more or less agitated by the feeblest earth tremors, we have a relative motion; and pens, projecting from the percussion centre of the mass to a smooth writing surface on the frame, would trace a record of the disturbance.

But the mass will not stand in this unstable position without some means of support. It must be attached to the frame, without being so bound to it, that it may not remain stationary when the frame oscillates. This is effected by two thrust rods, which meet in the centre of oscillation of the mass at an angle of 90° and thence extend, each to the short arm of a lever, whose fulcrum is rigidly fixed to the frame, and whose long arm works against a spring. The pressure of these two springs opposes the pull of gravity acting on the mass, which is slightly displaced from the vertical position. The mass, therefore, will find its position of equilibrium at a point in which the acting components of the two accelerations, g and ϕ (gravity and spring) are just equal and opposite. When the mass is displaced from this position, the components of both ϕ and g are changed. If moved farther from the vertical, both are increased; if nearer, both are diminished.

If they change at the same rate, there will be no fixed point of equilibrium, and the mass will stand in any position whatever. Hence ϕ and g must be so related that, in whatever direction the mass is displaced, a restoring force will be set up tending to bring it back to the equilibrium point; in short, it must be made to act like a pendulum. This will obtain if the component of ϕ increases more rapidly than that of g, when the mass is deflected from the vertical; and decreases more rapidly than the g-component when deflected towards the vertical.

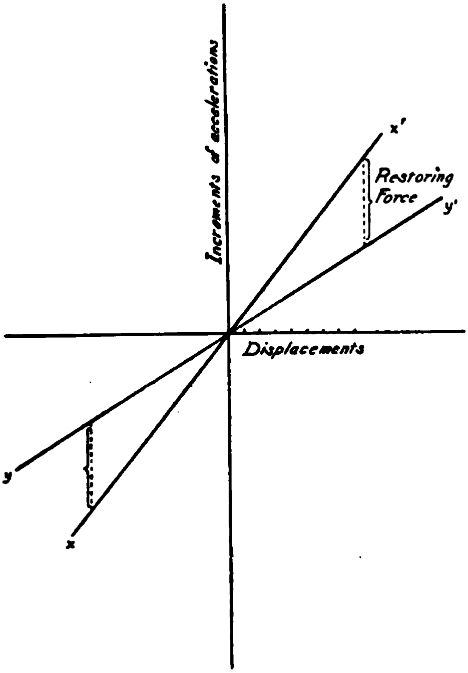


Fig. 1.

The restoring force might be represented graphically, by plotting, as abscissae, the displacements of the mass; as ordinates, the corresponding increments in the ϕ and g-components. (See Fig. 1.) These sets of points will determine two straight lines, xx' representing the successive increments of the ϕ-component; and yy' those of the g-component. xx' is a straight line because all harmonic motions vary directly with the displacement; and the same holds for yy', because of the very short range, never more than 2 mm., within which the movement of the mass is confined. The difference between the ordinates at any point will represent the resultant acceleration or restoring force which drives the mass back to the equilibrium point, represented by the origin of co-ordinates, where the components of ϕ and g are equal and opposite. If the mass is displaced, the restoring force will carry it back to and beyond the point of equilibrium by virtue of the kinetic energy developed. Hence the mass, like a pendulum, will execute harmonic motion, and will have its own definite period. This, however, may be changed at will by adjusting the leverage through which the spring acts on the mass. Shortening the arm connected with the latter, lessens the distance through which the mass must move to set up a given force of restitution, and hence shortens the period; while lengthening this arm has the opposite effect.

These levers serve another purpose. It is through them that the desired magnification on the gram is secured. The long arm in each case operates one of the recording pens, and hence, any movement transmitted to the latter will be multiplied on the record in the ratio of the long to the short arm of the lever system. This we might style the lever magnification. It remains practically constant. Fluctuations in magnification are due to other causes.

The pens are delicately balanced so that the pressure on the smoked paper amounts to about 1 milligram. The paper is carried around on a revolving drum at a uniform rate of 1 cm. per minute. The hours and minutes are automatically registered by an electro-magnet connected with the contact clock. The instrument is now ready to record an impulse from any direction. An impetus traveling parallel to the one of the thrust rods will affect only the pen connected with it, leaving the other undisturbed. Hence the mass is really equivalent to two distinct pendulums; there are two planes of independent vibration, viz.: the vertical planes passing through the thrust rods, and cutting each other at right angles. Vibrations parallel to neither of the thrust rods, will be split into two components, each of which will be recorded by the corresponding pen. The relative magnitudes on the record will depend on the angle formed by the direction of the vibrations with the independent planes, which, in our instrument, pass through the cardinal points of the compass.

One more adjunct, well-nigh essential to the proper working of the instrument, deserves mention before we pass on to the discussion of the constants. This is the damping contrivance. Its purpose is to "damp out" the vibrations due to the proper period of the pendulum, which would be set up by a sudden, strong impulse. Strong impulses, unless checked, would keep the mass in motion for a considerable time, and hence obliterate or accentuate any earth tremors, which might follow, thus falsifying the record. Such a disturbing element must be eliminated. The damping holds the mass in check, preventing it, to a great extent, from executing its own vibrations, and tending to keep it approximately at rest. The device consists of a cylindrical air chamber, in which moves to and fro, a piston connected by a rod to the lever system. The resistance of the air in the chamber opposes and minimizes the pendulum's independent action. This is different from friction in the ordinary sense of the term, which must always be kept at a minimum. The friction is a constant quantity, so that, if it curtails the stroke of the pen in one direction by 2 mm., it will curtail it by the same amount on the return stroke, etc. Not so the damping. This is not constant in amount, and is called forth by, and varies with the acceleration of the motion it is to oppose. Hence it will shorten the successive strokes of the pen by a constantly decreasing amount—the successive amplitudes will be a decreasing geometrical series. Thus the mass keeps itself from being thrown into violent swinging by strong earth disturbances, without losing, to any great extent, its sensitiveness to minute tremors.

THE PHYSICS OF THE SEISMOGRAPH.

Since the seismograph record is not a reliable index, of the intensity of a seismic disturbance, it is desirable to go back to the earth-motion itself. But the reduction of the recorded amplitudes to those of the actual earth-waves, involves a knowledge of several characteristic physical constants on which the magnifying power of the instrument depends. The term "constants" may be a bit misleading, for the factors in question are not constant in the sense that they may be measured once for all. Owing to changes produced by fluctuations in temperature and humidity, or, by violent earth shocks, etc., they are subject to variation, and hence, must be determined from time to time, especially after any readjustment.

The seismograph, as we have said, is an inverted pendulum; hence, it has a free period of its own, T_0. This is one of the constants, and is the time required for a complete oscillation of the pendulum set in motion, and left to itself, free from all exterior hindrances, such as damping, etc. Since the period is comparatively long, there is no difficulty in obtaining it by direct observation, provided the damping can be thrown out. The interval required for three, four or five oscillations of the pen, can be read off on a stop-watch. This number of seconds divided by the number of complete oscillations, will give the period quite accurately. The average of several such results may be taken as final. This, of course, must be repeated for each component.

Now, the seismograph pendulum is kept in equilibrium, by springs, as it could not oscillate, because of its inverted position, if the force of gravity were in control. We can not, therefore, apply to it the formula, $T = 2\pi\sqrt{\frac{l}{g}}$. For, instead of g we have an acceleration $(\phi - g)$, which is the resultant of the two opposing accelerations, gravity (g)

and the spring (ϕ). Hence the above formula must be changed to. $T_0 = 2\pi\sqrt{\frac{l}{\phi - g}}$ (1). Both ϕ and g are accelerations of the same character (harmonic), and therefore, their difference is harmonic, and may be expressed in cm/sec ^{2}. ϕ can not be equal to g, for an infinite period would result; that is, the pendulum, if deflected, would remain deflected. ϕ is, therefore, greater than g.

If ϕ is unknown, then $\phi - g$ is also unknown, and, hence, observing T_0 can not give l, the length of the actual seismograph pendulum. We may, however, infer the following: Let it be assumed that $\phi - g$ is wholly gravitational. Then: $T_0 = 2\pi\sqrt{\frac{L}{g}}$ (2), that is, some length, L, can be found, having the period T_0, upon the assumption that g is the acceleration. This L is the length of the equivalent mathematical pendulum. Therefore, our machine is "equivalent" to a simple gravitational pendulum of Length L, and period T_0. This equivalent length L is another of the constants.

In Figure 2, let CM represent the equivalent pendulum, which is suspended at C, and whose mass is concentrated at M. To make the simple pendulum record its vibrations with the same magnification as the actual seismograph, imagine a long pointer P (without mass), to be attached to M (thus prolonging L), so that it can be made to trace a line on the surface "S," when M moves to M'. Call the distance $L + P$, I. If I is given the proper length, the trace SS' on the surface "S" will equal the throw a of the pen on the actual seismograph for equal displacements of the two masses. Let this displacement be MM'. Now, from similar triangles, I is to L, as SS' is to MM'; but the ratio of SS' to MM' is the number expressing how many times larger SS' is than MM'. It is, therefore, the magnification; call it V. Then $V = \frac{I}{L}$ (3). Hence to determine the magnification, we need only the values of L and I. L, as we have said, can be determined from the observed period of the actual seismograph. I may also be found experimentally in the following manner:

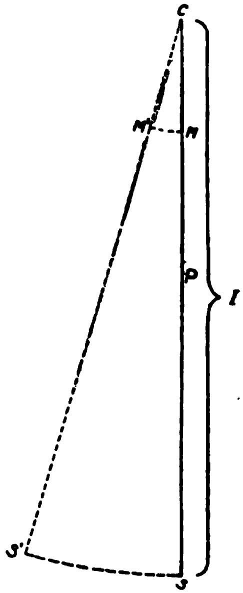


FIG. 2.

In Figure 3, which is exaggerated for the sake of clearness, let H be the distance in the actual seismograph from the center of gravity M' of the pendulum to the center of suspension C in the cardanic spring system.

Now if the center of gravity m of a small weight be placed at a known distance d from the line CM', the pendulum will shift to a new position of equilibrium, so that the center of gravity will now be at M'', and a certain throw a of the pen will be observed. Since all displacements of M from the vertical are small, the arcs = sines = tangents approximately. For the same reason $O'C = O''C = O'''C = H$, and $mO' = d$ approximately.

In position M', the moment about $C = M\,(\phi - g) \cdot H \tan \theta'$.

In position M'', the moment about $C = M\,(\phi - g) \cdot H \tan \theta''$.

The difference is caused by mg, whose moment is $mg \cdot H \tan \omega$.

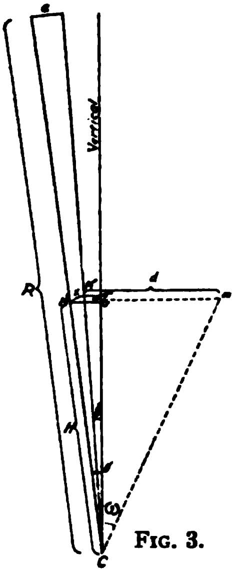


FIG. 3.

Hence, $M\,(\phi - g) \cdot H\,(\tan \theta' - \tan \theta'') = mg \cdot H \tan \omega$.

Or, $M\,(\theta' - \theta'') = m \tan \omega \dfrac{g}{\phi - g}$.

Since angle $(\theta' - \theta'') = \dfrac{x}{H}$, and $\tan \omega = \dfrac{d}{H}$, $M\dfrac{x}{H} = m\dfrac{d}{H} \cdot \dfrac{g}{\phi - g}$. (4).

Now, suppose the pen, instead of being operated by the compound lever system, were at the end of a long pointer CM' and CM'' produced to a length R such that the arc sweep through by the pen-tip would be exactly equal to a (see above), the throw of the actual pen observed when operated by the lever system.

Then $\dfrac{x}{H} = \dfrac{a}{R}$.

Substituting $M\dfrac{a}{R} = m\dfrac{d}{H} \cdot \dfrac{g}{\phi - g}$,

Or $\dfrac{M \cdot H \cdot a}{m \cdot d} = \dfrac{g}{\phi - g} \cdot R$ (5).

But, $\dfrac{L}{g} = \dfrac{T_0^2}{4\pi^2} = \dfrac{l}{\phi - g}$, (from (1) and (2) above).

Hence, $\dfrac{g}{\phi - g} = \dfrac{L}{l}$.

Substituting in (5) $\dfrac{M \cdot H \cdot a}{m \cdot d} = \dfrac{L}{l} R$ (6).

Since the center of suspension and the center of percussion (call it P, see Fig. 4) in any pendulum are interchangeable, if C is moved rapidly P will remain stationary. And as the writing plane moves with C, $\frac{a}{x} = \frac{C'S''}{CP}$ (from similar triangles). Now, $\frac{a}{x}$ is the magnification which we called V, $C'S''$ is R and CP is l.

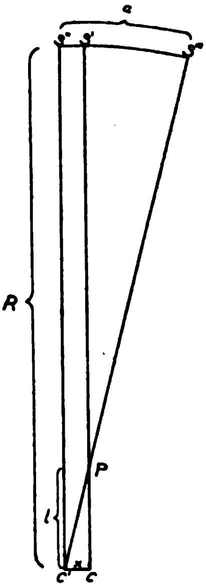


Fig. 4.

$$\text{Hence, } V = \frac{R}{l}.$$

$$\text{But we said above, } V = \frac{I}{L}$$

$$\text{therefore, } \frac{R}{l} = \frac{I}{L}$$

$$\text{and, } \frac{RL}{l} = I$$

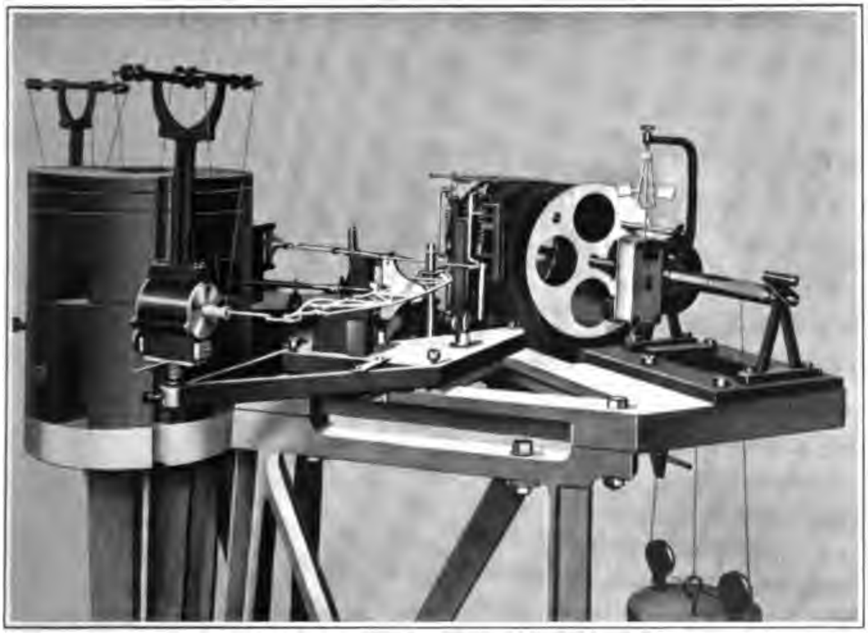
$$\text{substituting in (6) } \frac{M \cdot H \cdot a}{m \cdot d} = I \text{ (7).}$$

Hence, we can determine I experimentally from the known quantities, M, H, m, d and the resulting throw a of the pen (not riding on the smoked paper). Hence, we can find V. Since, however, on account of the mode of suspension, the single seismograph is equivalent to two pendulums, swinging at right angles, I (and hence V) must be found for each component. But one experiment will suffice if the small mass is placed in the plane bisecting the angle formed by the vertical planes passing through the thrust-rods, and the pen-throws a_E and a_N read off. The above formula then becomes $I = \frac{M \cdot H \cdot a}{.707\, m \cdot d}$.

Now V is the magnification only when the ratio $\frac{T_e}{T_0}$ (earth-period to machine period) is very small. That V is not the magnification for all values of T_e may be seen from the following consideration:

In Figure 5 a coiled spring is shown, supporting a mass W. If the point of support A is suddenly raised or lowered and then held fixed again, W will begin to oscillate with its own "free period," the amplitude depending on the permanent displacement of A.

If A is very suddenly raised or lowered, and as suddenly returned to position again, no matter how often in succession, provided this



Magnifying and Registering Apparatus.

vibration of A is of very short time-period compared to the "free" period of W, W will not be set in motion appreciably. It will begin to oscillate when A is vibrated more slowly. But the period of W will not be its "free" period nor that of A; neither will the amplitudes of W differ greatly from those of A. When the A vibration gets within about 99% of the free period, W will begin to plunge violently. The phenomenon therefore, appears rather suddenly, as it depends on small changes in the difference of the two periods. Moreover, the excursions of W will not be of constant amplitude; W will run up to a maximum excursion—then gradually diminish, and for an instant come to a full stop (of course, A is supposed to be kept moving steadily with fixed amplitude and period). Then W begins the performance over again. The action resembles that of "beats" in acoustics. The "beat" has a period of its own.

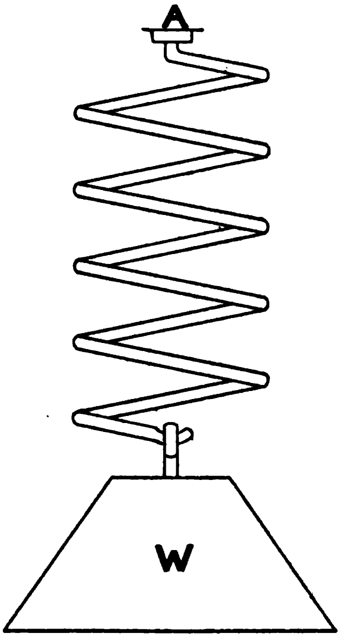


FIG. 6.

Let A be now moved with a period equal to the "free" period of W. W promptly falls into 1/2 phase with A, and the "beat" becomes infinitely long. That is, the amplitude of W goes on increasing indefinitely. Meantime A need not move with anything like large amplitude.

This effect is the well-known phenomenon called resonance.

As soon as the period of A becomes ever so little greater than the W "free" period, the latter will again be hampered in its vibrations. And should A move up and down much more slowly than the W period, W will simply begin to go up and down with A.

Applied to the seismograph, the frame and support will correspond to A, and the stationary mass to W. Hence, the "stationary" mass will only remain stationary when earth periods are very small. This is the only condition in which V will give the true magnification, which we may call $\mathfrak{V}$. When T_e approaches T_0, $\mathfrak{V}$ will become greater and greater, and when the two periods coincide $\mathfrak{V}$ would be theoretically infinite. When T_e becomes greater than T_0, $\mathfrak{V}$ decreases very rapidly and even falls far below V. This irregularity in the values of $\mathfrak{V}$ is another phase of the difficulty which makes necessary the introduction of damping. Small earth motions of a period near that of the machine are exaggerated beyond all proportion, while vibrations of greater amplitude, but also of longer period, are nearly suppressed. Damping tends to reduce "resonance" to a minimum, and hence to equalize the magnification curve.

In this case the true magnification $\mathfrak{V}$ for a given earth period may be found from Dr. Wiechert's formula:[2]

$$\mathfrak{V}=\frac{V}{\sqrt{\left[1-\left(\frac{T_e}{T_0}\right)^2\right]^2+4\left(\frac{T_0}{2\pi\tau}\right)^2\left(\frac{T_e}{T_0}\right)^2}}$$

τ being the time required for the amplitude of free vibrations to fall to $\frac{1}{e}$ of their original value, *i. e.*, to a fraction of the original value equal to the reciprocal of e, the base of the natural logarithms. Since $T_0=\frac{T}{\sqrt{1+\left(\frac{T}{2\pi\tau}\right)^2}}$ and log. nat. $\epsilon=\frac{T}{2\tau}$, (T being the period of the instrument when damped), the above formula may be reduced to the following:

$$\mathfrak{V}=\frac{V}{\sqrt{\left[1-\left(\frac{T_e}{T_0}\right)^2\right]^2+4\frac{(\text{log. nat. }\epsilon)^2}{\pi^2+(\text{log. nat. }\epsilon)^2}\cdot\left(\frac{T_e}{T_0}\right)^2}}$$

In this formula ϵ is the damping measured in terms of the ratio of two succeeding pen-amplitudes. This may be determined in the following manner:

Let the zero or mid-point of a graduated arc be made to coincide with the zero-line or neutral position of the pen, balanced so as to swing clear of the scale beneath. An impulse given to the lever controlling the pen will set the mass and pen in motion, and the displacement to either side may be read from the scale. Three such readings suffice; let them be a_1 to the right of 0; a_2 to the left of 0; a_3 to the right of 0 again. Then $\epsilon=\frac{a_1+a_2}{a_2+a_3}$, or with pen writing on the paper $\epsilon=\frac{a_1+a_2-2r}{a_2+a_3+2r}$, where r is the "maximum friction amplitude," i. e., the maximum distance to which the pen-point may be displaced without setting up a restoring force sufficient to overcome the friction opposing its return to the line of rest. We may obtain r independently by the following formula:

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[2] Dr. E. Wiechert — *Die Theorie der Automatischen Seismographen*,— Abhand d. K. Gesellsch. d. Wiss. zu Göttingen, Math.-Phys. Kl., 1903.

$r = \frac{1}{2} \frac{l_1^2 - l_0 l_2}{l_0 - l_2}$, where l_0, l_1, l_2, are successive double amplitudes from turning point to turning point (pen writing on paper). This formula can only be applied if the damping can be thrown out. The advantage of the latter method is that a permanent record of the damping test is obtained.

The constants T, L, I, V, ϵ, r definitely characterize an instrument as to its magnifying effect on a given earth motion. Hence, if they are known, any recorded seismic disturbance can be described in terms of the actual earth motion. This leads us to the practical working out of the seismogram.

THE PHASE ANALYSIS OF THE DIAGRAM.

Before taking up this subject, however, we must premise a few remarks on the nature of earthquakes in general. The theory of earthquake propagation most widely accepted, at present, is that of Dr. E. Wiechert [3]. It would lead us beyond the scope of these pages, to enter into a discussion of the facts and hypotheses upon which this theory is based. Suffice it to say, that he is led, mainly by astronomical reasons, to the assumption of a rock mantle increasing in density with increasing depth, and finally merging into a uniform metallic nucleus. Now, if a disturbance be set up in such an elastic medium, two sets of waves will necessarily be sent out in all directions. One of these wave-trains will be longitudinal, like sound vibrations in air; the other, transverse, like those of light. Upon reaching the surface these vibrations will transform part of their energy into a complicated series of surface waves. Of these disturbances the longitudinal waves will necessarily travel fastest, the surface waves least rapidly. Hence the order at which they will arrive at a distant point on the surface will be first longitudinal, then transverse, then surface waves, among the latter of which the first to appear will be the so-called long or "Rayleigh" waves. These three sets of waves will be recognized on the seismograph record as the first preliminary, second preliminary and main phases of the disturbance. Again, the longitudinal and transverse elastic waves travel faster, the denser the medium through which they pass. Therefore, on the assumption made in the theory of Wiechert, their velocity should increase with their depth. Hence if a plane wave front (such as a small element—e. g., a_1 b_1, a_2 b_2, a_3 b_3, etc.—Cfr. Fig. 6—of the actual ovoidal wave front may be considered to be), traverses any other path than a diameter, one side will at first be passing through a denser medium than the other. As a consequence, this side will travel faster than the other, and the whole wave front will be swung around. In the middle core, however, both sides of the wave front will be traversing a medium of equal density, and the wave front will remain parallel to itself. Thus the ray or normal to the wave surface will describe a curved line in the rock mantle, and a straight line in the metallic core.

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[3] E. Wiechert and K. Zöppritz — *Ueber Erdbebenwellen I und II.* Nachr. d. K. Gesellsch. d. Wiss. zu Göttingen, Math.-Phys. Kl., 1907.

Furthermore, each of these disturbances will produce its effect independently of all the rest. Hence, whenever a longitudinal or transverse wave reaches the surface, it will be reflected independently, according to the laws which govern elastic waves[4].

(A) A longitudinal wave striking the surface will be reflected in two components, one longitudinal with the angle of reflection equal to the angle of incidence; the other, transverse, with a lesser angle of reflection. The sines of the two angles are directly proportional to the velocities of the corresponding waves (in the same medium, of course).

(B) There are two cases possible in the reflection of transverse waves:

(a) When the vibration takes place perpendicularly to the plane of incidence (i. e., the plane which contains the normal to the surface, the angle of incidence and the angle of reflection), only one wave, similar to the incident one is reflected, and this at an angle equal to the angle of incidence.

(b) When, however, the transverse wave is vibrating in the plane of incidence a resolution of component motions will take place at the surface. And, if the angle of incidence i is smaller than the *critical* value (sin $i = \left(\frac{\textit{velocity of transverse wave}}{\textit{velocity of longitudinal wave}} \right)$, two waves will be reflected, the one transverse, at an angle equal to the angle of incidence, the other longitudinal at a much greater angle, the sines of the two angles being again directly proportional to their velocities. If, on the other hand, the incident ray makes an angle with the normal greater than the critical value, then no longitudinal wave can be reflected, but very complex surface-disturbances will be set up instead.

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[4] See Wiechert, Note 3.

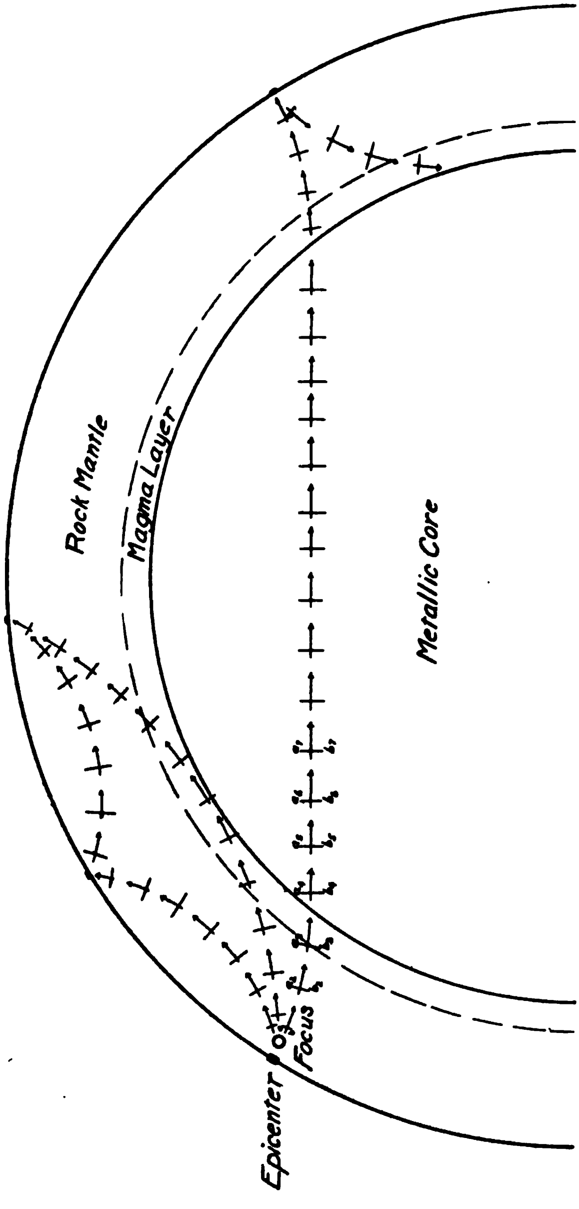

FIG. 6.

Now it is evident, that if the paths and velocities of the direct waves in the preliminary phases are known, the velocities of the reflected and transformed waves may be derived from them. An absolutely necessary requisite to further progress, therefore, is to obtain arrival curves for the principal phases which will be as accurate as possible. Such curves were constructed by Milne (1903), Benndorf (1905), Oldham (1906) and others, but the most reliable results so far obtained, are those contained in the Göttingen curves and tables[5]. The original tables gave the time in seconds required by each phase to travel from the epicenter to successive stations one-half megameter (1 megameter = 1000 km.) apart up to a distance of 13 megameters. The following is an arrangement of these tables giving time-differences in minutes and seconds and embodying interpolations to 100 km. of Dr. Conrad[6] and some of our own.

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[5] See Note 3, and K. Zöppritz and L. Geiger — *Über Erdbebenwellen III.* Nachr. d. K. Gesellsch. d. Wiss. zu Göttingen, Math.-Phys. Kl., 1909.

[6] Dr. V. Conrad — *Seismische Registrierungen in Wien*, K. k. Akad. d. Wiss., Neue Folge., No. 39.

I. TABLE FOR DISTANCES.

Distance	Epicenter by Stereographic Projection		Distance		PHASES										Angle of Emergence	
Statute Miles	"d" St. Louis	"r" St. Louis	Angular	Mega-Meters	S—P	R_1P—P	R_2P—P	R_3P—P	PS—S	R_1S—S	R_2S—S	R_3S—S	eL—P	eL—S	P	S
					m s	m s	m s	m s	m s	m s	m s	m s	min	min		
	.4810	.00967	54′	0.1	....	....	....	....	....	....	....	....	....	....	......	......
100	.4811	.01934	1°48′	.2	....	....	....	....	....	....	....	....	....	....	......	......
200	.4813	.02902	2°42′	.3	....	....	....	....	....	....	....	....	....	....	......	......
	.4815	.0387	3°36′	.4	....	....	....	....	....	....	....	....	....	....	......	......
300	.4818	.04839	4°30′	.5	....	....	....	....	....	....	....	....	....	....	......	......
400	.4822	.05809	5°24′	.6	....	....	....	....	....	....	....	....	....	....	......	......
	.4827	.06781	6°18′	.7	....	....	....	....	....	....	....	....	....	....	......	......
500	.4833	.07753	7°12′	.8	....	....	....	....	....	....	....	....	....	....	......	......
	.4839	.08728	8° 6′	.9	....	....	....	....	....	....	....	....	....	....	......	......
600	.4846	.09704	9° 0′	1.0	1 48	....	....	....	....	....	....	....	1.9	.1	20°42′	20°42′
700	.4854	.1068	9°54′	1.1	1 58	....	....	....	....	....	....	....	2.1	.1	22°29′	22°29′
	.4862	.1166	10°48′	.2	2 8	....	....	....	....	....	....	....	2.3	.2	24°16′	24°16′
800	.4872	.1265	11°42′	.3	2 17	....	....	....	....	....	....	....	2.5	.2	26° 3′	26° 3′
	.4882	.1363	12°36′	.4	2 27	....	....	....	....	....	....	....	2.7	.2	27°50′	27°50′
900	.4892	.1462	13°30′	.5	2 37	....	....	....	....	....	....	....	2.9	.3	29°37′	29°37′
1,000	.4904	.1561	14°24′	.6	2 46	....	....	....	....	....	....	....	3.1	.8	31° 9′	31° 9′
	.4916	.1661	15°18′	.7	2 55	....	....	....	....	....	....	....	3.4	.5	32°40′	32°40′
1,100	.4930	.1761	16°12′	.8	3 5	....	....	....	....	....	....	....	3.6	.5	34°12′	34°12′
1,200	.4944	.1861	17° 6′	.9	3 14	....	....	....	....	....	....	....	3.8	.6	35°43′	35°43′
	.4959	.1961	18° 0′	2.0	3 23	0 15	0 18	0 19	....	0 28	0 34	0 36	4.0	.6	37°15′	37°15′
1,300	.4974	.2063	18°54′	.1	3 31	0 17	0 21	0 22	....	0 32	0 39	0 42	4.3	.8	38°32′	38°32′
	.4991	.2164	19°48′	.2	3 40	0 19	0 24	0 25	....	0 35	0 44	0 48	4.5	.8	39°49′	39°49′
1,400	.5008	.2266	20°42′	.3	3 48	0 22	0 27	0 28	....	0 39	0 48	0 54	4.8	1.0	41° 6′	41° 6′
1,500	.5027	.2369	21°36′	.4	3 57	0 23	0 30	0 31	....	0 42	0 53	1 0	5.0	1.0	42°23′	42°23′
1,600	.5046	.2472	22°30′	.5	4 5	0 25	0 33	0 34	....	0 46	0 58	1 6	5.3	1.2	43°40′	43°40′
	.5066	.2575	23°24′	.6	4 13	0 28	0 36	0 37	....	0 51	1 6	1 13	5.5	1.3	44°45′	44°45′
1,700	.5087	.2679	24°18′	.7	4 20	0 31	0 40	0 41	....	0 56	1 11	1 21	5.8	1.5	45°49′	45°49′
1,800	.5109	.2784	25°12′	.8	4 28	0 34	0 43	0 44	....	1 1	1 18	1 28	6.0	1.5	46°54′	46°54′
	.5131	.2890	26° 6′	.9	4 35	0 37	0 47	0 48	....	1 6	1 24	1 36	6.3	1.7	47°58′	47°58′
1,900	.5155	.2996	27° 0′	3.0	4 43	0 40	0 50	0 51	....	1 11	1 31	1 43	6.5	1.8	49° 3′	49° 3′
	.5180	.3103	27°54′	.1	4 50	0 43	0 55	0 56	....	1 17	1 39	1 51	6.8	2.0	49°54′	49°57′
2,000	.5206	.3210	28°48′	.2	4 57	0 46	0 59	1 1	....	1 23	1 47	1 59	7.1	2.1	50°44′	50°51′
2,100	.5232	.3318	29°42′	.3	5 3	0 49	1 4	1 6	....	1 29	1 54	2 8	7.3	2.2	51°35′	51°45′
	.5260	.3428	30°36′	.4	5 10	0 52	1 8	1 11	....	1 35	2 2	2 16	7.6	2.4	52°25′	52°39′
2,200	.5289	.3537	31°30′	.5	5 17	0 55	1 13	1 16	....	1 41	2 10	2 24	7.9	2.6	53°16′	53°32′
	.5319	.3648	32°24′	.6	5 23	0 58	1 17	1 21	....	1 47	2 18	2 33	8.2	2.8	53°58′	54°17′
2,300	.5350	.3760	33°18′	.7	5 29	1 4	1 22	1 26	....	1 53	2 26	2 41	8.4	2.9	54°40′	55° 4′
2,400	.5382	.3873	34°12′	.8	5 35	1 5	1 26	1 32	....	1 59	2 33	2 50	8.7	3.1	55°23′	55°49′
	.5415	.3986	35° 6′	.9	5 41	1 9	1 31	1 37	....	2 5	2 41	2 58	9.0	3.3	56° 5′	56°35′
2,500	.5449	.4101	36° 0′	4.0	5 47	1 12	1 35	1 42	....	2 11	2 49	3 7	9.3	3.5	56°47′	57°20′
	.5486	.4216	36°54′	.1	5 53	1 16	1 40	1 47	....	2 17	2 58	3 17	9.6	3.7	57°26′	57°59′
2,600	.5523	.4333	37°48′	.2	5 59	1 20	1 45	1 53	....	2 24	3 7	3 27	9.9	3.9	58° 5′	58°37′
2,700	.5561	.4451	38°42′	.3	6 4	1 24	1 49	1 58	....	2 30	3 16	3 36	10.2	4.1	58°43′	59°16′
	.5600	.4570	39°36′	.4	6 10	1 28	1 54	2 4	....	2 37	3 25	3 46	10.5	4.3	59°22′	59°54′
2,800	.5641	.4690	40°30′	.5	6 16	1 32	1 59	2 9	....	2 43	3 34	3 56	10.8	4.5	60° 1′	60°33′
2,900	.5684	.4811	41°24′	.6	6 21	1 35	2 4	2 15	....	2 50	3 43	4 7	11.1	4.7	60°34′	60°54′
	.5727	.4934	42°18′	.7	6 26	1 38	2 9	2 21	....	2 57	3 53	4 18	11.4	5.0	61° 8′	61°14′
3,000	.5772	.5058	43°12′	.8	6 31	1 42	2 13	2 26	....	3 3	4 2	4 29	11.7	5.2	61°41′	61°35′
	.5819	.5184	44° 6′	.9	6 36	1 45	2 18	2 32	....	3 10	4 12	4 40	12.0	5.4	62°15′	61°55′
3,100	.5867	.5311	45° 0′	5.0	6 41	1 48	2 23	2 38	0 11	3 17	4 21	4 51	12.3	5.6	62°48′	62°16′
3,200	.5917	.5439	45°54′	.1	6 47	1 52	2 29	2 44	0 12	3 23	4 30	5 2	12.6	5.8	63°11′	62°18′
	.5968	.5569	46°48′	.2	6 52	1 56	2 35	2 51	0 14	3 29	4 40	5 13	12.9	6.0	63°34′	62°20′
3,300	.6021	.5701	47°42′	.3	6 58	1 59	2 40	2 57	0 15	3 34	4 49	5 24	13.3	6.3	63°56′	62°23′
3,400	.6076	.5834	48°36′	.4	7 3	2 3	2 46	3 4	0 17	3 40	4 59	5 35	13.6	6.5	64°19′	62°25′
	.6133	.5969	49°30′	.5	7 9	2 7	2 52	3 10	0 19	3 46	5 8	5 46	13.9	6.7	64°42′	62°27′
3,500	.6191	.6106	50°24′	.6	7 14	2 10	2 57	3 17	0 20	3 52	5 17	5 58	14.2	7.0	64°43′	62°31′
3,600	.6252	.6245	51°18′	.7	7 20	2 14	3 3	3 24	0 22	3 57	5 26	6 6	14.5	7.2	64°44′	62°35′
	.6314	.6386	52°12′	.8	7 25	2 17	3 8	3 30	0 23	4 3	5 34	6 16	14.8	7.4	64°45′	62°40′
3,700	.6378	.6519	53° 6′	.9	7 31	2 21	3 14	3 37	0 24	4 8	5 43	6 26	15.1	7.6	64°46′	62°44′
3,800	.6444	.6673	54° 0′	6.0	7 36	2 24	3 19	3 44	0 25	4 14	5 52	6 36	15.5	7.9	64°47′	62°48′
	.6513	.6821	54°54′	.1	7 41	2 27	3 24	3 50	0 27	4 19	6 0	6 47	15.8	8.1	64°49′	62°51′
3,900	.6584	.6971	55°48′	.2	7 47	2 30	3 29	3 56	0 29	4 23	6 8	6 57	16.1	8.3	64°52′	62°55′
	.6658	.7123	56°42′	.3	7 52	2 33	3 35	4 2	0 30	4 28	6 17	7 8	16.5	8.6	64°54′	62°58′
4,000	.6733	.7277	57°36′	.4	7 58	2 36	3 40	4 8	0 32	4 32	6 25	7 18	16.8	8.8	64°57′	63° 2′

Distance	Epicenter by Stereographic Projection		Distance		PHASES										Angle of Emergence	
Statute Miles	"d" St. Louis	"r" St. Louis	Angular	Mega-Meters	S—P	R_1P—P	R_2P—P	R_3P—P	PS—S	R_1S—S	R_2S—S	R_3S—S	eL—P	eL—S	P	S
					m s	m s	m s	m s	m s	m s	m s	m s	min	min		
4,100	.6812	.7434	58°30′	.5	8 3	2 39	3 45	4 14	0 33	4 37	6 33	7 29	17.1	9.0	64°59′	63° 5′
	.6892	.7594	59°24′	.6	8 8	2 42	3 50	4 20	0 33	4 41	6 41	7 39	17.4	9.3	65° 3′	63°11′
4,200	.6976	.7757	60°18′	.7	8 13	2 45	3 55	4 26	0 34	4 45	6 48	7 48	17.7	9.5	65° 7′	63°16′
4,300	.7062	.7922	61°12′	.8	8 19	2 47	4 0	4 31	0 34	4 50	6 56	7 58	18.0	9.7	65°11′	63°22′
	.7152	.8091	62° 6′	.9	8 24	2 50	4 5	4 37	0 35	4 54	7 3	8 7	18.3	9.9	65°14′	63°27′
4,400	.7244	.8262	63° 0′	7.0	8 29	2 53	4 10	4 43	0 35	4 58	7 11	8 17	18.6	10.1	65°18′	63°33′
	.7340	.8437	63°54′	.1	8 34	2 55	4 14	4 49	0 35	5 1	7 19	8 27	18.9	10.3	65°23′	63°39′
4,500	.7439	.8616	64°48′	.2	8 39	2 57	4 18	4 54	0 35	5 5	7 27	8 37	19.3	10.6	65°28′	63°45′
4,600	.7541	.8798	65°42′	.3	8 44	2 59	4 22	5 0	0 36	5 8	7 35	8 47	19.6	10.9	65°32′	63°50′
	.7647	.8984	66°36′	.4	8 49	3 1	4 26	5 5	0 36	5 12	7 43	8 57	20.0	11.2	65°37′	63°56′
4,700	.7757	.9174	67°30′	.5	8 54	3 3	4 30	5 11	0 36	5 15	7 51	9 7	20.3	11.4	65°42′	64° 2′
4,800	.7871	.9368	68°24′	.6	8 59	3 6	4 34	5 17	0 36	5 18	7 58	9 16	20.6	11.6	65°48′	64° 9′
	.7989	.9566	69°18′	.7	9 5	3 8	4 39	5 23	0 37	5 21	8 4	9 25	20.9	11.8	65°54′	64°16′
4,900	.8111	.9769	70°12′	.8	9 10	3 11	4 43	5 28	0 37	5 23	8 11	9 33	21.3	12.1	65°59′	64°22′
	.8238	.9976	71° 6′	.9	9 16	3 13	4 48	5 34	0 38	5 26	8 17	9 42	21.6	12.3	66° 5′	64°29′
5,000	.8369	1.0189	72° 0′	8.0	9 21	3 16	4 52	5 40	0 38	5 29	8 24	9 51	21.9	12.5	66°11′	64°36′
5,100	.8506	1.0407	72°54′	.1	9 26	3 18	4 56	5 46	0 39	5 32	8 31	10 0	22.2	12.8	66°18′	64°44′
	.8648	1.0630	73°48′	.2	9 31	3 19	5 0	5 51	0 40	5 34	8 38	10 10	22.5	13.0	66°25′	64°51′
5,200	.8795	1.0859	74°42′	.3	9 35	3 21	5 3	5 57	0 40	5 37	8 45	10 19	22.9	13.3	66°31′	64°59′
	.8948	1.1093	75°36′	.4	9 40	3 22	5 7	6 2	0 41	5 39	8 52	10 29	23.2	13.5	66°38′	65° 6′
5,300	.9107	1.1440	76°30′	.5	9 45	3 24	5 11	6 8	0 42	5 42	8 59	10 38	23.5	13.7	66°45′	65°14′
5,400	.9272	1.1583	77°24′	.6	9 50	3 26	5 15	6 13	0 43	5 44	9 5	10 47	23.8	14.0	66°52′	65°22′
	.9444	1.1838	78°18′	.7	9 55	3 28	5 19	6 19	0 43	5 47	9 11	10 56	24.1	14.2	67° 0′	65°30′
5,500	.9623	1.2100	79°12′	.8	10 0	3 29	5 23	6 24	0 44	5 49	9 17	11 4	24.5	14.5	67° 7′	65°39′
	.9810	1.2370	80° 6′	.9	10 6	3 31	5 27	6 30	0 44	5 52	9 23	11 13	24.8	14.7	67°15′	65°47′
5,600	1.0005	1.2650	81° 0′	9.0	10 11	3 33	5 31	6 35	0 45	5 54	9 29	11 22	25.1	14.9	67°22′	65°55′
5,700	1.0208	1.2936	81°54′	.1	10 16	3 35	5 35	6 40	0 46	5 56	9 35	11 31	25.4	15.1	67°30′	66° 4′
	1.0420	1.3233	82°48′	.2	10 21	3 37	5 38	6 45	0 47	5 58	9 41	11 39	25.8	15.4	67°38′	66°13′
5,800	1.0639	1.3540	83°42′	.3	10 25	3 40	5 42	6 51	0 49	6 1	9 47	11 48	26.1	15.7	67°47′	66°23′
	1.0872	1.3856	84°36′	.4	10 30	3 42	5 45	6 56	0 50	6 3	9 53	11 56	26.5	16.0	67°55′	66°32′
5,900	1.1114	1.4183	85°30′	.5	10 35	3 44	5 49	7 1	0 51	6 5	9 59	12 5	26.8	16.2	68° 3′	66°41′
6,000	1.1369	1.4523	86°24′	.6	10 40	3 45	5 53	7 6	0 52	6 7	10 5	12 13	27.1	16.4	68°12′	66°51′
	1.1634	1.4875	87°18′	.7	10 44	3 46	5 57	7 11	0 54	6 8	10 11	12 22	27.4	16.7	68°21′	67° 0′
6,100	1.1912	1.5240	88°12′	.8	10 49	3 47	6 2	7 15	0 55	6 10	10 17	12 30	27.8	17.0	68°30′	67°10′
6,200	1.2204	1.5620	89° 6′	.9	10 53	3 48	6 6	7 20	0 57	6 11	10 23	12 39	28.1	17.2	68°39′	67°19′
	1.2511	1.6011	90° 0′	10.0	10 58	3 49	6 10	7 25	0 58	6 13	10 29	12 47	28.4	17.4	68°48′	67°29′
6,300	1.2834	1.6427	90°54′	.1	11 2	3 50	6 13	7 31	0 59	6 16	10 35	12 56	28.7	17.7	68°57′	67°39′
	1.3174	1.6855	91°48′	.2	11 7	3 50	6 16	7 36	1 0	6 19	10 40	13 4	29.1	18.0	69° 6′	67°50′
6,400	1.3532	1.7303	92°42′	.3	11 11	3 51	6 20	7 42	1 0	6 21	10 46	13 13	29.4	18.2	69°16′	68° 0′
	1.3910	1.7771	93°36′	.4	11 16	3 51	6 23	7 47	1 1	6 24	10 51	13 21	29.8	18.5	69°25′	68°11′
6,500	1.4310	1.8260	94°30′	.5	11 20	3 52	6 26	7 53	1 2	6 27	10 57	13 30	30.1	18.8	69°34′	68°21′
6,600	1.4732	1.8774	95°24′	.6	11 24	3 54	6 30	7 58	1 3	6 29	11 2	13 39	30.4	19.0	69°44′	68°32′
	1.5172	1.9313	96°18′	.7	11 28	3 55	6 34	8 3	1 4	6 31	11 8	13 47	30.8	19.3	69°54′	68°42′
6,700	1.5654	1.9880	97°12′	.8	11 33	3 57	6 37	8 8	1 6	6 33	11 13	13 56	31.1	19.5	70° 3′	68°53′
6,800	1.6198	2.0476	98° 6′	.9	11 37	3 58	6 41	8 13	1 7	6 35	11 19	14 4	31.5	19.9	70°13′	69° 3′
	1.6694	2.1110	99° 0′	11.0	11 41	4 0	6 45	8 18	1 8	6 37	11 24	14 13	31.8	20.1	70°23′	69°14′
6,900	1.7266	2.1772	99°54′	.1	11 45	4 1	6 49	8 23	1 10	6 40	11 29	14 19	32.1	20.3	70°34′	69°26′
	1.7876	2.2477	100°48′	.2	11 49	4 2	6 52	8 27	1 11	6 43	11 35	14 25	32.5	20.7	70°44′	69°38′
7,000	1.8530	2.3226	101°42′	.3	11 53	4 3	6 56	8 32	1 13	6 45	11 40	14 32	32.8	20.9	70°55′	69°49′
7,100	1.9230	2.4022	102°36′	.4	11 57	4 4	6 59	8 36	1 15	6 48	11 46	14 38	33.2	21.2	71° 6′	70° 1′
	1.9982	2.4872	103°30′	.5	12 1	4 5	7 3	8 41	1 16	6 51	11 51	14 44	33.5	21.5	71°17′	70°13′
7,200	2.0793	2.5780	104°24′	.6	12 5	4 7	7 6	8 46	1 18	6 54	11 56	14 54	33.8	21.7	71°28′	70°25′
7,300	2.1669	2.6754	105°18′	.7	12 9	4 9	7 9	8 50	1 20	6 57	12 2	15 4	34.2	22.0	71°39′	70°37′
	2.2612	2.7802	106°12′	.8	12 13	4 12	7 12	8 55	1 22	7 1	12 7	15 15	34.5	22.3	71°51′	70°49′
7,400	2.3654	2.8941	107° 6′	.9	12 17	4 14	7 15	8 59	1 24	7 4	12 13	15 25	34.9	22.6	72° 2′	71° 1′
7,500	2.4770	3.0156	108° 0′	12.0	12 21	4 16	7 18	9 4	1 26	7 7	12 18	15 35	35.2	22.8	72°13′	71°13′
	2.5999	3.1496	108°54′	.1	12 25	4 17	7 22	9 9	1 28	7 10	12 24	15 44	35.5	23.1	72°25′	71°25′
7,600	2.7349	3.2938	109°48′	.2	12 28	4 19	7 25	9 15	1 31	7 14	12 30	15 52	35.9	23.4	72°36′	71°38′
7,700	2.8834	3.4527	110°42′	.3	12 32	4 20	7 29	9 20	1 33	7 17	12 35	16 1	36.2	23.7	72°48′	71°50′
	3.0483	3.6280	111°36′	.4	12 35	4 22	7 32	9 26	1 36	7 21	12 41	16 9	36.6	24.0	72°59′	72° 3′
7,800	3.2320	3.8222	112°30′	.5	12 39	4 23	7 36	9 31	1 38	7 24	12 47	16 18	36.9	24.2	73°11′	72°15′
	3.4377	4.0386	113°24′	.6	12 42	4 25	7 39	9 36	1 40	7 28	12 53	16 26	37.3	24.6	73°22′	72°27′
7,900	3.6696	4.2812	114°18′	.7	12 46	4 27	7 42	9 41	1 42	7 32	12 58	16 34	37.6	24.8	73°34′	72°40′
8,000	3.9333	4.5557	115°12′	.8	12 49	4 29	7 46	9 45	1 45	7 35	13 4	16 41	38.0	25.2	73°45′	72°52′
	4.2353	4.8685	116° 6′	.9	12 53	4 31	7 49	9 50	1 47	7 39	13 9	16 49	38.3	25.4	73°57′	73° 5′
8,100	4.5845	5.2290	117° 0′	13.0	12 56	4 33	7 52	9 55	1 49	7 43	13 15	16 57	38.7	25.8	74° 9′	73°17

The phase analysis of diagrams is greatly facilitated by such an arrangement of the tables. To use them, we determine approximately the beginning of the three principal phases of the earthquake recorded on the diagram, and obtain the time differences, S-P, eL-P, and eL-S, in minutes and seconds. With these we enter the respective columns of the table, and note the corresponding distances. If they agree approximately, we may suppose that we have rightly identified the phases as present on our record. In that case we need only make sure that our time determinations are correct; and the epicentral distance thus obtained, may be considered fairly certain. If, however, the distances obtained for the three time differences do not agree, then, either we have mistaken the phases, or, some phase or part of phase is missing from our diagram. The latter is not at all improbable, for scarcely one-fourth of the seismograms obtained in the course of a year, will be complete. The correct interpretation of such an imperfect record, is by no means an easy matter, and will require careful comparison and study. To avoid complications, let us suppose that the diagram before us is a perfect one, and the epicentral distances agree. We then run through the entire line, corresponding to the distance we have found in the table, and note the time-difference for each reflection. With these we go back to the diagram, and examine it carefully. If any or all of the reflections actually appear at the time indicated, this will be an additional confirmation of the determined epicentral distance. The relative values of the vertical and horizontal impulses may also be of assistance in estimating the distance, and for this reason, we have added the tables of angles of emergence, derived by linear interpolation and subtraction from 90°, according to Dr. Geiger's table of angles of incidence[7].

But even with the distance accurately determined, the position of the earthquake epicenter is by no means fixed. Call the distance "Δ". Then the locus of epicenters is the circumference of a circle, whose arcual radius is "Δ". If, however, we could ascertain the direction or azimuth of the epicenter, then, evidently, its position would be absolutely fixed; for it would be the point of intersection of the locus and the line of azimuth. Now, on some records, the first preliminary tremors begin with a well-defined impetus, and, as these waves are longitudinal in character, this impulse must have traveled along the line of propagation of the wave itself. Hence, if we know the specific behavior of our seismograph, under an impulse from each of the cardinal points, we can conclude to the direction, by applying the principle of the parallelogram of forces to the impulses on each component. This method, however, applies only to the cases mentioned which begin with a sudden impulse, and even then is somewhat uncertain. For we can never be quite sure, in the case of distant earthquakes, that the very first impulse was recorded. Besides, the direction thus obtained, is the direction from which the wave was coming, the moment it reached the instrument, not necessarily that of the epicenter. But for the sake of the probable estimate, which can often be made thus, it is of advantage to have a map, on which lines of equal distance and like direction from the seismograph are drawn. Such maps were constructed for Ischia, Rome, Laibach, Hamburg, Uccle, Jugenheim[8].

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[7] See Note 5.

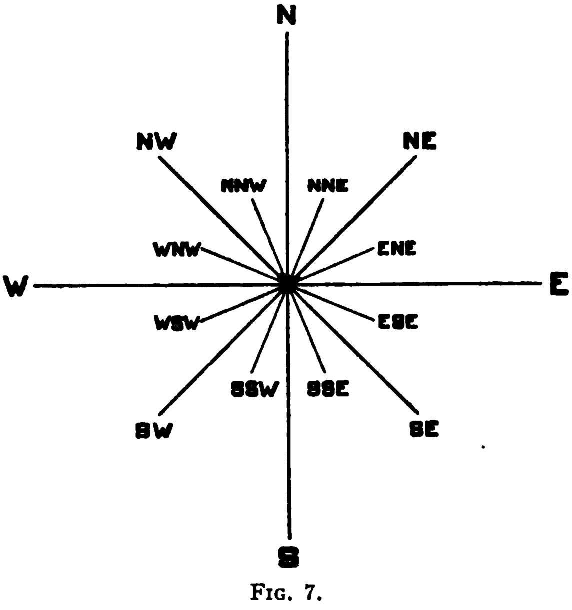

FIG. 7.

To construct the map, the directions shown in the accompanying figure (Fig. 7) were chosen and the geographical positions computed for points along each of these lines, 1000 km., 2000 km., etc., up to 20000 km. distant from St. Louis.

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[8] Dr. C. Zeissig—*Koordinaten-Tafeln für d. Seismische Station Darmstadt-Jugenheim*, 1909.

The accompanying table contains the co-ordinates of these points. 1000 km. was taken as 9°, and the co-ordinates of St. Louis roundly as 38° 38′ N. Lat. and Long. 90° 14′ W.

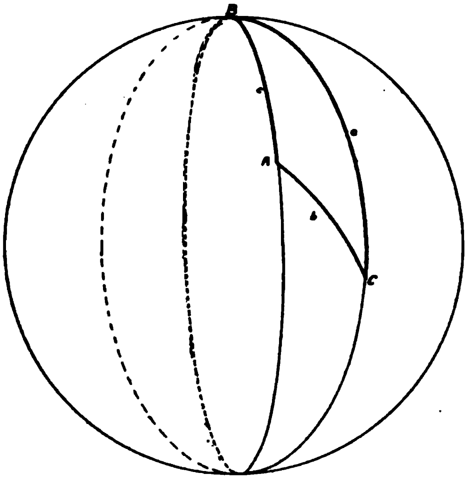

FIG. 8.

In the figure (Fig. 8) let A be St. Louis, B the North Pole, C one of the points whose co-ordinates are to be found. Then in the spherical triangle ABC the side c is known, being the polar distance of St. Louis $(90°—\phi)$; b is the arcual distance chosen, and A is the angle included between the distance chosen and the meridian N. of St. Louis. With these three quantities chosen, we can compute a, the polar distance of the point whose co-ordinates are sought; and B, the difference in longitude, by means of the trigonometric formulas:

$$\tan \frac{1}{2}(B+C) = \frac{\cos \frac{1}{2}(b-c)}{\cos \frac{1}{2}(b+c)} \cot \frac{1}{2} A$$

$$\tan \frac{1}{2}(B-C) = \frac{\sin \frac{1}{2}(b-c)}{\sin \frac{1}{2}(b+c)} \cot \frac{1}{2} A$$

$$\cos \frac{1}{2} a = \frac{\cos \frac{1}{2}(b+c)}{\cos \frac{1}{2}(B+C)} \sin \frac{1}{2} A$$

II. COÖRDINATES FOR ST. LOUIS.

Distance from St. Louis	N		NNW		NW		WNW	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1,000......	47°38′ N	90°14′ W	46°48′ N	95°15′ W	44°46′ N	99°11′ W	41°30′ N	101°22′ W
2,000......	56°38′ N	90°14′ W	55° 0′ N	102° 4′ W	49°58′ N	110° 3′ W	43°22′ N	113°21′ W
3,000......	65°38′ N	90°14′ W	61°58′ N	112° 2′ W	53°48′ N	123°10′ W	43°48′ N	125°46′ W
4,000......	74°38′ N	90°14′ W	67°46′ N	127°45′ W	56° 6′ N	138°22′ W	42°50′ N	138° 5′ W
5,000......	83°38′ N	90°14′ W	72° 6′ N	152° 8′ W	56°12′ N	154°34′ W	40°44′ N	149°49′ W
6,000......	87°22′ N	90°14′ W	71°22′ N	178°23′ E	54°28′ N	170° 7′ W	37°34′ N	160°40′ W
7,000......	78°22′ N	89°46′ E	68° 0′ N	154°43′ E	50°50′ N	176°15′ E	33°22′ N	170°28′ W
8,000......	69°22′ N	89°46′ E	61° 8′ N	139°36′ E	45°46′ N	164°55′ E	28°34′ N	179°19′ E
9,000......	60°22′ N	89°46′ E	54° 6′ N	129°57′ E	40° 0′ N	155°34′ E	23° 4′ N	172°40′ E
10,000......	51°22′ N	89°46′ E	46°34′ N	123°19′ E	33°24′ N	147°48′ E	17°22′ N	165°16′ E
11,000......	42°22′ N	89°46′ E	37°54′ N	118°25′ E	26°44′ N	141° 8′ E	11°20′ N	158°20′ E
12,000......	33°22′ N	89°46′ E	29°32′ N	114°30′ E	19°24′ N	125°15′ E	5°22′ N	151°41′ E
13,000......	24°22′ N	89°46′ E	20° 0′ N	111°12′ E	11°42′ N	130°53′ E	0°48′ S	145°11′ E
14,000......	15°22′ N	89°46′ E	10°48′ N	108°16′ E	5° 0′ N	124°46′ E	6°38′ S	138°39′ E
15,000......	6°32′ N	89°46′ E	3°50′ N	105°30′ E	3°10′ S	119°49′ E	13°18′ S	131°56′ E
16,000......	2°38′ S	89°46′ E	4°24′ S	102°49′ E	10°22′ S	114°46′ E	19°12′ S	124°53′ E
17,000......	11°38′ S	89°46′ E	13°12′ S	100° 3′ E	17°52′ S	109°28′ E	24°52′ S	117°18′ E
18,000......	20°38′ S	89°46′ E	21°48′ S	97° 5′ E	25° 0′ S	103°43′ E	30° 6′ S	109° 2′ E
19,000......	29°38′ S	89°46′ E	30°14′ S	93°45′ E	32° 2′ S	97°16′ E	34°44′ S	99°54′ E
20,000......	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E

Distance from St. Louis	W		WSW		SW		SSW	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1,000......	38° 4′ N	101°42′ W	34°44′ N	100°22′ W	32° 2′ N	97°43′ W	30° 4′ N	94°12′ W
2,000......	36°24′ N	112°49′ W	30° 6′ N	109°30′ W	25° 2′ N	104°12′ W	21°46′ N	79°33′ W
3,000......	33°48′ N	123°21′ W	24°52′ N	117°46′ W	17°48′ N	109°56′ W	13°14′ N	100°31′ W
4,000......	30°20′ N	133°10′ W	19°14′ N	125°21′ W	10°24′ N	115°14′ W	4° 38′ N	103°17′ W
5,000......	26°12′ N	142°14′ W	13°18′ N	132°24′ W	2°56′ N	120°17′ W	3°56′ S	105°58′ W
6,000......	21°32′ N	150°39′ W	7°12′ N	139° 7′ W	4°36′ S	125°15′ W	12°32′ S	108°44′ W
7,000......	16°26′ N	158°32′ W	1° 0′ N	145°39′ W	12° 2′ S	130°21′ W	21° 4′ S	111°40′ W
8,000......	11°10′ N	166° 0′ W	5°16′ S	152° 9′ W	19°24′ S	135°43′ W	29°34′ S	114°58′ W
9,000......	5°38′ N	173°11′ W	11°24′ S	158°48′ W	26°36′ S	141°36′ W	37°58′ S	118°53′ W
10,000......	0° 0′	179°46′ E	17°24′ S	165°44′ W	33°32′ S	148°16′ W	46°12′ S	123°47′ W
11,000......	5°36′ S	172°43′ E	23° 8′ S	173° 8′ W	40° 2′ S	156° 2′ W	54° 8′ S	130°25′ W
12,000......	11° 8′ S	165°32′ E	28°30′ S	178°51′ E	45°54′ S	165°23′ W	61°34′ S	143° 0′ W
13,000......	16°34′ S	158° 4′ E	33°22′ S	170° 0′ E	50°52′ S	176°43′ W	67°54′ S	155°11′ W
14,000......	21°18′ S	150°11′ E	37°40′ S	160°12′ E	54°24′ S	169°39′ E	71°58′ S	178°51′ W
15,000......	26°18′ S	141°46′ E	40°48′ S	149°21′ E	56°20′ S	154° 6′ E	72° 8′ S	151°40′ E
16,000......	30°38′ S	132°42′ E	42°54′ S	137°37′ E	56° 4′ S	137°54′ E	68°20′ S	127°17′ E
17,000......	33°48′ S	122°53′ E	43°48′ S	125°17′ E	53°48′ S	122°42′ E	62°16′ S	111° 3′ E
18,000......	36°26′ S	112°21′ E	36°20′ S	112°53′ E	49°52′ S	109°34′ E	54°46′ S	101°36′ E
19,000......	38° 4′ S	101°14′ E	41°34′ S	100°54′ E	44°40′ S	98°43′ E	46°50′ S	94°47′ E
20,000......	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E

Distance from St. Louis	S		SSE		SE		ESE	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1,000	29°38′ N	90°14′ W	30° 4′ N	86°16′ W	32° 2′ N	82°45′ W	34°44′ N	80° 6′ W
2,000	20°38′ N	90°14′ W	21°46′ N	82°55′ W	25° 2′ N	76°16′ W	30° 6′ N	70°58′ W
3,000	11°38′ N	90°14′ W	13°14′ N	79°57′ W	17°48′ N	70°32′ W	24°52′ N	62°42′ W
4,000	2°38′ N	90°14′ W	4°38′ N	77°11′ W	10°24′ N	65°14′ W	19°14′ N	55° 7′ W
5,000	6°22′ S	90°14′ W	3°56′ S	74°30′ W	2°56′ N	60°11′ W	13°18′ N	48° 4′ W
6,000	15°22′ S	90°14′ W	12°32′ S	71°44′ W	4°36′ S	55°13′ W	7°12′ N	41°21′ W
7,000	24°22′ S	90°14′ W	21° 4′ S	68°48′ W	12° 2′ S	50° 7′ W	1° 0′ N	34°49′ W
8,000	33°22′ S	90°14′ W	29°34′ S	65°30′ W	19°24′ S	44°45′ W	5°16′ S	28°19′ W
9,000	42°22′ S	90°14′ W	37°58′ S	61°35′ W	26°36′ S	38°52′ W	11°24′ S	21°40′ W
10,000	51°22′ S	90°14′ W	46°12′ S	56°41′ W	33°32′ S	32°12′ W	17°24′ S	14°44′ W
11,000	60°22′ S	90°14′ W	54° 8′ S	50° 3′ W	40° 2′ S	24°26′ W	23° 8′ S	7°20′ W
12,000	69°22′ S	90°14′ W	61°34′ S	40°25′ W	45°54′ S	15° 5′ W	28°30′ S	0°41′ E
13,000	78°22′ S	90°14′ W	67°54′ S	25°17′ W	50°52′ S	3°45′ W	33°22′ S	9°32′ E
14,000	87°22′ S	90°14′ W	71°58′ S	1°37′ W	54°24′ S	9°53′ E	37°40′ S	19°21′ E
15,000	83°38′ S	89°46′ E	72° 8′ S	27°52′ E	56°20′ S	25°26′ E	40°48′ S	30°11′ E
16,000	74°38′ S	89°46′ E	68°20′ S	52°15′ E	56° 4′ S	41°38′ E	42°54′ S	41°55′ E
17,000	65°38′ S	89°46′ E	62°16′ S	68°29′ E	53°48′ S	56°50′ E	43°48′ S	54°15′ E
18,000	58°38′ S	89°46′ E	54°46′ S	77°56′ E	49°52′ S	69°58′ E	43°20′ S	66°39′ E
19,000	47°38′ S	89°46′ E	46°50′ S	84°45′ E	44°40′ S	80°49′ E	41°34′ S	78°38′ E
20,000	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E

Distance from St. Louis	E		ENE		NE		NNE	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1,000	38° 4′ N	78°46′ W	41°30′ N	79° 6′ W	44°46′ N	81°17′ W	46°48′ N	85°13′ W
2,000	36°24′ N	67°39′ W	43°22′ N	67° 7′ W	49°58′ N	70°25′ W	55° 0′ N	78°24′ W
3,000	33°48′ N	57° 7′ W	43°48′ N	54°42′ W	53°48′ N	57°18′ W	61°58′ N	68°26′ W
4,000	30°20′ N	47°18′ W	42°50′ N	42°23′ W	56° 6′ N	42° 6′ W	67°46′ N	52°43′ W
5,000	26°12′ N	38°14′ W	40°44′ N	30°39′ W	56°12′ N	25°54′ W	72° 6′ N	28°20′ W
6,000	21°32′ N	29°49′ W	37°34′ N	19°48′ W	54°28′ N	10°21′ W	71°22′ N	1° 9′ E
7,000	16°26′ N	21°56′ W	33°22′ N	10° 0′ W	50°50′ N	3°17′ E	68° 0′ N	24°49′ E
8,000	11°10′ N	14°28′ W	28°34′ N	1° 9′ W	45°46′ N	14°37′ E	61° 8′ N	39°56′ E
9,000	5°38′ N	7°17′ W	23° 4′ N	6°52′ E	40° 0′ N	23°58′ E	54° 6′ N	49°35′ E
10,000	0° 0′	0°14′ W	17°22′ N	14°16′ E	33°24′ N	31°44′ E	46°34′ N	56°13′ E
11,000	5°36′ S	6°49′ E	11°20′ N	21°12′ E	26°44′ N	38°25′ E	37°54′ N	61° 7′ E
12,000	11° 8′ S	14° 0′ E	5°22′ N	27°51′ E	19°24′ N	44°17′ E	29°32′ N	65° 2′ E
13,000	16°34′ S	21°28′ E	0°48′ N	34°21′ E	11°42′ N	49°39′ E	20° 0′ N	68°20′ E
14,000	21°18′ S	29°21′ E	6°38′ S	40°53′ E	5° 0′ N	54°45′ E	10°48′ N	71°16′ E
15,000	26°18′ S	37°46′ E	13°18′ S	47°36′ E	3°10′ S	59°43′ E	3°50′ N	74° 2′ E
16,000	30°38′ S	46°50′ E	19°12′ S	54°39′ E	10°22′ S	64°46′ E	4°24′ S	76°43′ E
17,000	33°48′ S	56°39′ E	24°52′ S	62°14′ E	17°52′ S	70° 4′ E	13°12′ S	79°29′ E
18,000	36°26′ S	67°11′ E	30° 6′ S	70°30′ E	25° 0′ S	75°49′ E	21°48′ S	82°27′ E
19,000	38° 4′ S	78°18′ E	34°44′ S	79°38′ E	32° 2′ S	82°16′ E	30°14′ S	85°47′ E
20,000	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E	38°38′ S	89°46′ E

The calculation was done with 6-place logarithms without interpolation for seconds, which gives a possible error of ± 1′, sufficiently near for any ordinary map. Since this calculation involves considerable labor, a less satisfactory substitute, may be found in a globe, on which a few guide points have been plotted by the above method, and the curves carefully drawn through them. Some such device is practically indispensable for estimating the position of an epicenter from the observations of one station.

If, however, the observations of at least three stations, a considerable distance apart, are available, then the position of the epicenter can be found by any one of several methods. The method of least squares, no matter how applied, requires considerable time. That of stereographic projection, however, is rapid and the calculations are extremely simple[9]. Take an accurate circle of unit radius, whose circumference is graduated in both directions from a point 0°, to an opposite point, 180°. Take the longitude of one of the stations, find the point corresponding to the same number of degrees E. or W., on the circle, and draw a radius to that point. On this radius lay off from the center a distance $d = \frac{\cos \phi}{\sin \phi + \cos \Delta}$. With the point thus found as center, and a radius $r = \frac{\sin \Delta}{\sin \phi + \cos \Delta}$, draw an arc. Do the same for each of the other stations. Through the center of gravity of the resulting polygon of intersection (which should be very small if the data are correct), draw another radius. Then the longitude of the epicenter can be read off at once at the end of this radius, and the distance from the center of gravity of the polygon to the center of the circle, expressed as above in terms of the radius $= \tan (45° - \frac{1}{2} \phi)$. To assist those who may wish to make use of our data, we have added to Table I, a table of St. Louis "*d*" and "*r*," for successive hundreds of km. The accuracy of the stereographic method depends on the size and exactness of the circle used.

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[9] Dr. Otto Klotz — *Earthquake Epicenters.* — Journal of Astron. Soc. of Canada, May-June, 1910.

THE KINETIC AND DYNAMIC ANALYSIS.

The kinetic analysis of earthquake records is carried out in the St. Louis University Observatory according to approved methods. The periods and diagram amplitudes are read with a filar micrometer microscope. For the reduction of record amplitudes to earth particle amplitudes, it is necessary to work out a new table of magnifications, $\mathfrak{V}$, or better, $\frac{1000}{\mathfrak{V}}$, to obtain unit amplitude directly in microns (1 micron = 1 μ = .001 mm.) for all common values of $\frac{T_e}{T_0}$ after each change in the constants of the instrument. To do this for each component independently by solution of the equation:

$$\mathfrak{V} = \frac{V}{\sqrt{\left(1-\left(\frac{T_e}{T_0}\right)^2\right)^2 + 4\,\frac{(\log \text{nat } \epsilon)^2}{\pi^2 + (\log \text{nat } \epsilon)^2}\left(\frac{T_e}{T_0}\right)^2}} = \frac{V}{\sqrt{S}}$$

for all values of $\frac{T_e}{T_0}$ that may be needed, is no child's task, and any assistance that tends to lessen this drain on an observer's time is most welcome. To this end Dr. Geiger's tabulated ratios of $\frac{T_e}{T_0}$ and his logarithmic curves for corresponding values of $\sqrt{S}$ are invaluable, and reduce the work of hours to that of a few minutes.[10]

The determination of the maximum motion in the main phase sometimes requires several preliminary trials. For one wave may have a slightly greater diagram amplitude, another a longer period; hence, which of the two has the greater earth amplitude can only be seen from the reduction of both. However, in such cases, both the waves will generally be inserted in the report as M_1 and M_2. These amplitudes, however, are no safe measure of the violence of a shock. The true criterion of earthquake intensities is the earth-particle acceleration, and this is very readily obtained by the handy formula $\frac{4A}{T_e^2}$. For if the earth-particle amplitude (A) is expressed in microns, the period in seconds, and the acceleration in milligals (1 milligal = .001 gal = $10\mu/\text{sec.}^2$ = .000001 g approximately), then the harmonic acceleration formula $\frac{4\pi^2 A}{T^2}$ reduces approximately to the above simple form. This deduction of the earth acceleration from the earth particle amplitude and period, we may call the dynamic analysis of the seismogram. It is published regularly by several seismic observatories.

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[10] Dr. L. Geiger — *Seismische Registrierungen in Göttingen in Jahre* 1908. Nach d. K. Gessellsch. d. Wiss. zu Göttingen, Math.-Phys. Kl. 1909.

EARTHQUAKES REGISTERED IN ST. LOUIS UNIVERSITY OBSERVATORY DURING 1910.

The following is a list of the earthquakes recorded by our 80 kg. Wiechert astatic, horizontal pendulum during the past year 1910. We are sorry to say that, with the exception of the month of December, when we began to determine the instrument constants more accurately, the magnification was too uncertain to admit of the calculation of earth particle amplitudes from the amplitudes recorded on the seismogram. Hence for the first eleven months we have simply given the diagram "double" amplitudes ($2a$), expressed in mm. Beginning with December we substitute the earth-particle amplitude (A) in μ. The nomenclature used in characterizing the phases, etc., is that originated by Drs. Weichert and Geiger of the University of Göttingen[11]. This form, with its Latin symbols, which has been aptly styled "The International" by Rev. F. L. Odenbach, S. J., is so simple, so concise and so adaptable, that it bids fair to come into universal use. It has been adopted by most of the great Seismological Observatories of Germany, all those of Austria, some of Italy, Servia, by the U. S. Weather Bureau, the Dominion Observatory of Canada, the National Geological Institute of Mexico, and the Tsingtau Observatory in China, and by most of the observatories conducted by the Jesuit Fathers in Syria, Australia, Spain, Canada and the United States. The symbols are as follows:

SYMBOLS.

(GOETTINGEN NOMENCLATURE.)

CHARACTER OF THE EARTHQUAKE.

I = noticeable, II = striking, III = violent.

d = (terrae motus domesticus) = local earthquake (felt at station).

v = (terrae motus vicinus) = nearby earthquake (less than 1000 km.).

r = (terrae motus remotus) = distant earthquake (1000-5000 km.).

u = (terrae motus ultimus) = very distant earthquake (more than 5000 km.).

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[11] Dr. L. Geiger — *Seismische Registrierungen in Göttingen in Jahre* 1907. Nachr. d. K. Gesellsch. d. Wiss. zu Göttingen, Math.-Phys. Kl.

PHASES:

P = (undae primae) = first preliminary tremors (longitudinal waves through the earth's interior).

PRn = P waves reflected n times at the earth's surface.

S = (undae secundae) = second preliminary tremors (transverse waves through the earth's interior).

SRn = S waves reflected n times at the earth's surface.

PS = transformed waves, i. e., waves which, in their reflection at the earth's surface, have been changed from longitudinal to transverse, or vice versa.

L = (undae longae) = long or "Rayleigh" waves (first phase of main or principal portion—surface waves).

M = (undae maximae) = greatest motion in the main or principal portion (complicated surface waves).

C = (cauda) after-shocks or trailers.

F = (finis) = end of visible motion.

NATURE OF THE MOTION:

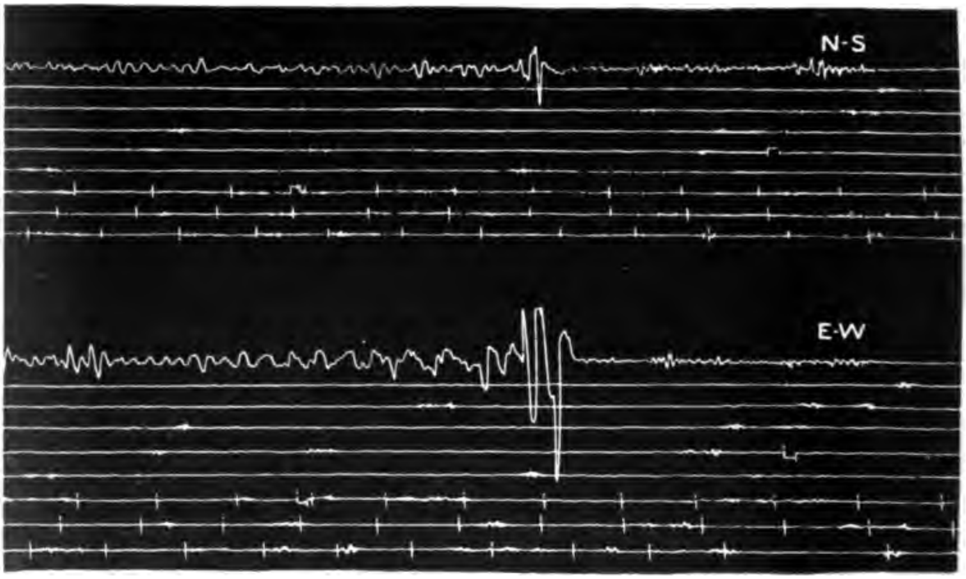
i = (impetus) = sudden impulse.

e = (emersio) = gradual development (beginning uncertain).

T = period = time of complete vibration to and fro.

A = amplitude of earth motion—reckoned from the line of rest and measured in microns ($\mu = \frac{1}{1000}$ mm).

E or N attached to a symbol refers it to the E-W or N-S component.



Seismogram of Jan. 1, 1910.

Jesuit Seismological Service Record of the Earthquake Station, St. Louis University

ST. LOUIS, MO., U. S. A.

LATITUDE: 38° 38′ 17″ N.
LONGITUDE: 90° 13′ 58″.5 or 6^h 0^m $55^s.9$ W. Gr.

TIME: Mean Greenwich, midnight to midnight.
INSTRUMENT: Wiechert 80 kg., astatic, horizontal pendulum.

NOMENCLATURE: Goettingen.

FROM JANUARY 1st TO DECEMBER 31st.

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					2AE	*2AN*	
			h. m.	s.	*mm*	*mm*	
Jan. 1	IIIr	P_N	11 06.3	7			Δ=2440 km.
		P_E	11 06.6	6			Earthquake reported from Swan Island. Caribbean Sea.
		S_E	11 10.3				
		S_N	11 10.3				
		i_E	11 10.7	21	21		
		i_N	11 10.9	12		8	
		C_N	11 21.8	10		5.5	
		C_E	11 27	12	3.7		
		C_{2N}	11 29	12		1	
		F_N	11 54.2				
		F_E	12 02.2				
Jan. 22	IIr	e_E	9 03.5				North of Iceland.
		e_N	9 03.5				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	mm	mm	
		eL_E	9 13	19	2.4		
		eL_N	13.1	13		.8	
		i_E	15	10	3.2		
		iM_{1E}	15.6	12	5		
		M_N	15.6	18		3.4	
		iM_{2E}	17	13	4.5		
		C_N	21.3	10		.6	
		C_E	21.4	11	.4		
		F_N	54				
		F_E	10 02				
Jan. 24	IIu	e_E	18 42.1	9	.6		
		e_N	42.3	6		.5	
		L_E	43.6				
		L_N	43.6				
		iM_E	43.7	10	10	4	
		iM_N	43.8	7			
		F_E	52				
		F_N	57				
Feb 4	I	e_E	15 04	15			No disturbance on N.-S.
		F	19				Continuous Waves on N.-S.
Feb. 7	I	e	3				
		F	6				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_N$	$2A_N$	
			h. m.	s.	*mm*	*mm*	
Feb. 28	II	eP_E	21 14.5				
		P_N	15.3				
		iS_E	22.3	10	.4		
		S_N	22.5	12		.4	
		L_N	24.8				
		L_E	25.1				
		M_{1E}	33.	12	.9		
		M_N	33.1	12			
		M_{2E}	37.1	10	.2		
		C_E	59.1				
		F_E	22 01.3				
Mar. 4	I	e_N	9 48				
		e_E	51				
		F	10 00				
Mar. 9	I	e_E	22 00				No disturbance on N-S.
		F_E	06				
Mar. 11		e	21 00				
		F	23 00				No record on E-W.
Mar. 30	II	P_N	17 45.1				
		eP_E	48.2				
		S_N	50.5	18		.6	
		S_E	51.2	21	.3		

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_N$	$2A_N$	
			h. m.	s.	*mm*	*mm*	
		eL_E	18 00.5				
		M_{1E}	01.8	15	1.1		
		M_{2E}	05	13	1.1		
		M_{3E}	08.8	18	1.2		
		L_N	10.3				
		M_N	11.5	18		.8	
		C_E	13.5				
		C_E	17.5				
		F_E	20.2				
		F_N	25.7				
Mar. 31	I	e	19 00				S and L very indistinct.
		F	29				
Apr. 26	I	e	23 32				
		F	40				
Apr. 27	I	e	0 57				
		F	1 00				
May 13	II	e_N	8 12.2				Costa Rica
		e_E	21.9				
		eL_N	28.2	10		.3	
		eL_E	28.8				
		M_{1N}	34.5	12		1.2	
		M_E	34.5	9	1		

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	mm	mm	
		M_{EN}	8 42	12	1.3	1.1	
		F_N	9 05.5				
		F_E	06.2				
May 19	I	e	6 18				
		F	21				
May 31	II	e_E	5 00.8				
		i_N	00.8	6		3.5	Very sudden shocks.
		i_E	04.9	6	3.5		
		eS	05				
		i_N	05.2	3		3	
		eL_E	09.6				
		eL_N	09.8				
		M_E	11.3	6	2		
		M_N	11.3	5		1.6	
		F	28.9				
June 1	I	e	7				
		L	01.5				
		M_E	02	18	.5		
		M_N	03	20		1	
		F_E	12				
		F_N	14				
June 16	II	P	18 56				L begins with M.

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	*mm*	*mm*	
		S_E	18 58				
		S_N	59				
		iM_E	59.7	18	5		
		iM_N	59.7	12		2.5	
June 29	I	e_E	11 39				
		S_E	40.2				Traces of six shocks on N-S Component but indistinct.
		L_E	41				
		M_{1E}	41.2	15	1.5		
		M_{2E}	53.9	15	1		
		M_{3E}	58.5	18	.9		
		F_E	12 30.1				
July 7	II	e_E	4 57.8				
		e_N	57.9				
		M_{1E}	58.5	9	8		M and L begin at the same time.
		M_{1N}	58.5	5		4	
		M_{2E}	04.3	7	1.9		
		M_{2N}	04.5	8		1.2	
		F_E	11				
		F_N	14				
Aug. 5	II	e	1 44.4				
		L_E	47.9				
		L_N	48.3				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	mm	mm	
		M_E	1 49.1	12	3		
		M_N	49.6	12		7.5	
		F	2 27				
Aug. 11	IIr	P	16 33.5				
		iS_E	39.6	12	1.5		
		iS_N	39.6	5		1.6	
		L_E	43.7				
		L_N	44				
		M_E	44	15	2		Amplitude interfered with by local motion.
		M_N	44.2	14			
		F_E	17 02				
		F_N	03				
Sept. 7	I	e_N	8 09	18			
		e_E	12	24	.3		
		F	20				
Sept. 7	I	e_N	10 49	15		.3	
		e_E	11 01				
		F_E	12				
		F_N	22				
Sept. 9	I	iP_E	1 30.5				
		P_N	31.6				
		L	40.2				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE $2A_E$	AMPLITUDE $2A_N$	REMARKS
			h. m.	s	mm	mm	
		M_{1E}	1 45.3	14	1.7		
		M_N	45.8	20		.9	
		M_{2E}	47.8	15	1.1		
		M_{3E}	49.8	12	1		
		F_N	2 13				
		F_E	14.7				
Sept. 16	I	e_N	19 03				
		e_E	08				
		F_N	24				
		F_E	25				
Sept. 24	II	P_N	3 35.5				P_E could not be determined.
		S	37.5				
		L	37.7				
		M_N	37.8	8		7	
		M_E	37.8	9	7.5		
		F_N	4 09				Overlapped by the following.
Sept. 24	I	P_N	15				
		S_E	16.5				
		S_N	17.3				
		L_E	17.3				
		iM_E	17.4	9	3		
		L_N	17.7				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	mm	mm	
		iM_E	4 17.9	9		1.7	
		F_N	25				
		F_E	29				
Oct. 4	II	eP	23 11				$\Delta = 6900$ km. At Antofogasta, Chile.
		iS	19.4				
		PS	20	6	2.7	1.7	
		i_{1E}	21.7	7	1.1		
		i_{2E}	22.5	6	.7		
		F_E	57				
		F_N	58				
Nov. 6	II	e	20 44				
		eS_N	47	4			
		eS_E	47	6			
		L_N	49	8		2.1	
		iL_E	49	8.5	2.9		
		M_E	51	11	3.2		
		M_N	52	9		2.3	
		iC_{1E}	54	7.5	3		
		iC_{1N}	55	7		1.2	
		C_{2E}	56	6	2.9		
		C_{3E}	58	7	1.1		
		C_{2N}	21 10	6		.7	

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	*mm*	*mm*	
		F_N	21 22				
		F_E	29				
Nov. 9	I	L_N	6 53	16		.3	
		L_E	56.5	16	.8		
		F_N	7 38				
		F_E	40				
Nov. 10	I	eL_N	3 18	22		.4	
		L_E	18	9	.3		
		F_E	4 08				
		F_N	20				
Nov. 10	I	e_N	12 47	18		.4	
		e_E	13 13	8	.3		
		eL_E	16	20	.6		
		L_N	18	15		.4	
		F_N	31				
		F_E	38				
Nov. 26	IIμ	e_E	5 10.5	18	.6		
		i_E	15.5	20	.8		
		eL_E	35	21	.5		
		M_{1E}	38	21	.7		
		M_{2E}	40	21	1.3		
		e_N	42				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					$2A_E$	$2A_N$	
			h. m.	s.	*mm*	*mm*	
Nov. 26	IIμ	M_{3E}	5 49	15	.8		
		M_{4E}	51	15	.7		
		M_N	52	16		.5	
		C_N	59			.3	
		F_E	6 06				
		F_N	19				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					A_E	A_N	
			h. m.	s.	μ	μ	
Dec. 7							Microseisms during the greater part of the day.
Dec. 10	I	e	10 00				
		L_N	20				
		eL_E	21	24			
		M_E	23	10	6		
		M_N	24	10		6	
		F_N	11 41				
		F_E	42				
Dec. 13	II	e_E	12 20				
		e_N	21				
		eL_N	30	30		16	
		M_N	35.8	21		95	
		iL_E	39	18			
		L_N	41	24		99	
		M_{1E}	42.9	16	46		
		M_{2E}	45	19	69		
		M_{3E}	45.5	19	69		
		M_{4E}	46.7	17	42		
		C_{1E}	50				
		C_{2E}	05				
		F_E	57				
		F_N	58				

DATE 1910	CHAR.	PHASE	TIME	PERIOD T.	AMPLITUDE		REMARKS
					A_E	A_N	
			h. m.	s.	μ	μ	
Dec. 16	IIμ	e_N	15 12	12		21	
		i_{1E}	24	14	18		
		i_{2E}	26	10	6		
		iL_{1E}	16 03.1	17	47		
		iL_{2E}	05	18	34		
		eM_E	07.7	16	41		
		L_N	10	18			
		L_E	12	14	19		
		M_N	14	21		91	
		C_{1E}	21	15	18		
		C_{2E}	30	15	15		
		C_{3E}	35	18	18		
		F_N	55				
		F_E	17 11				
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ACKNOWLEDGMENTS.

In conclusion, we wish to express our gratitude to those who assisted in the preparation of these pages, especially to the Rev. Henry DeLaak, S. J., Professor of Advanced Physics in St. Louis University. We take this opportunity also to thank those kind friends whose generous support has made the work of the Observatory possible. Our acknowledgments are also due to the following who, by their contributions and exchanges, have added much valuable material to the Observatory Library:

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The

Geophysical Observatory

Meteorological and Seismological Departments

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Meteorology in St. Louis University.

HISTORICAL OUTLINE. 1860-1910.

THE day on which the present observatory was opened, January 1, 1910, was the fiftieth anniversary of the first meteorological observatory begun at St. Louis University. Although the pioneer work had been interrupted long before the expiration of the half century, still it was an encouraging reality to those who, in happier times and with brighter prospects, fell heir to the invaluable records compiled with such scrupulous care by those early observers. Gratitude and respect for their efforts demand that we give more than a passing reference to the work accomplished by our predecessors.

Fifty years ago, at the request of the U. S. Government, meteorological observations were begun at the University. The station was located at what was then called "College Hill, a suburb of the city in St. Louis County." Latitude 38° 40′ north, Longitude 90° 15′ west. Mr. Francis H. Stuntebeck, S. J., then completing his studies in Theology at College Hill, was placed in charge and was assisted by Mr. John H. Luneman, S. J., of the Philosophy department. The ability and earnestness of these two pioneer observers is attested by the complete and careful records they have left us.

The first observations were taken on January 1, 1860, and consisted of readings of atmospheric pressure; maximum, minimum and mean temperatures; relative humidity; vapor pressure; precipitation; amount, kind, direction and velocity of clouds; direction and velocity of winds. Later, some of the instruments which had done service at St. Joseph's College, Bardstown, Ky., from 1857 till the closing of that institution in 1861, were transferred to the observatory on College Hill, St. Louis, Mo. During the year 1860 the efficiency of the observatory was lessened to such an extent by the encroachment of rendering establishments with their "two and seventy stenches, several and well-defined," and by foundries and rolling mills, that its location had to be changed. The instruments were removed to what was known as the Old College Building at Ninth and Washington Avenue, and Father Peter G. Koning, S. J., was appointed director. Father Koning determined the Latitude of the new station to be 38° 37′ 28″ north, Longitude 90° 15′ west, and the height above sea level as 470 feet.

On May 23, 1861, Rev. Father Ignatius Panken, S. J., long and lovingly remembered by the people of St. Louis, succeeded to the directorship.

On September 24, 1861, Mr. Luneman, the former assistant, was placed in charge, holding the office until July, 1864, when Father Stuntebeck returned to the observatory. The latter was succeeded in January, 1869, by Mr. Aloysius Averbeck, S. J., and he in turn by Mr. Michael Tracy, S. J., in 1873.

It was in 1873 that the U. S. Government opened its own station in the city within a few blocks of the University. The observatory was thus relieved of its official responsibility and deprived of much of its usefulness, and, as a result, we find no data after March 26, 1874.

For 14 years, during which this department of St. Louis University existed, we find besides the accurate daily tabulation of the data enumerated above, many interesting notes among the "casual phenomena." Under August 7, 1860, we read: "An earthquake at 9 hrs. 17 min. A. M. felt by persons at College Hill. Lasted about 15 sec. The number of oscillations was about 30. Direction seemed to be from east to west. No noise was heard. Oscillations very distinct."

Under July 23 is the note: "A brilliant meteor appeared in the sky about south of this place. It exploded nearly over the large building. Part of it fell on the building. It was seen by one of the Brothers and by many persons that were passing by. Next morning I went to examine the roof of the building (metallic), but found nothing except a wet spot, which became dry during the day."

An interesting succession of events is thus tabulated: "January 1, 1864, the coldest day for at least 31 years. The Minimum Thermometer of 'Green' fell as low as 20° below zero, F. Doctor Engelmann's (Green Thermometer, too) went as low as 22° below zero during the night."

January 2: "Mississippi frozen over. January 5, Government wagons crossing the Mississippi on the ice. January 27, River open below and opposite the city; ferry boats crossed yesterday, broke the ice. Above the city, persons are still crossing on the ice."

Under January 15, 1865, we read: "This morning at 6 o'clock four rings were seen around the moon; the nearest white, the second blue, the third yellow, and the fourth light green. These lasted for some 6 or 8 minutes and then gradually disappeared."

On January 16, 1866: "The river was gorged with ice yesterday. To-day it broke above the city. The floating ice destroyed some seven or eight boats at the city landing."

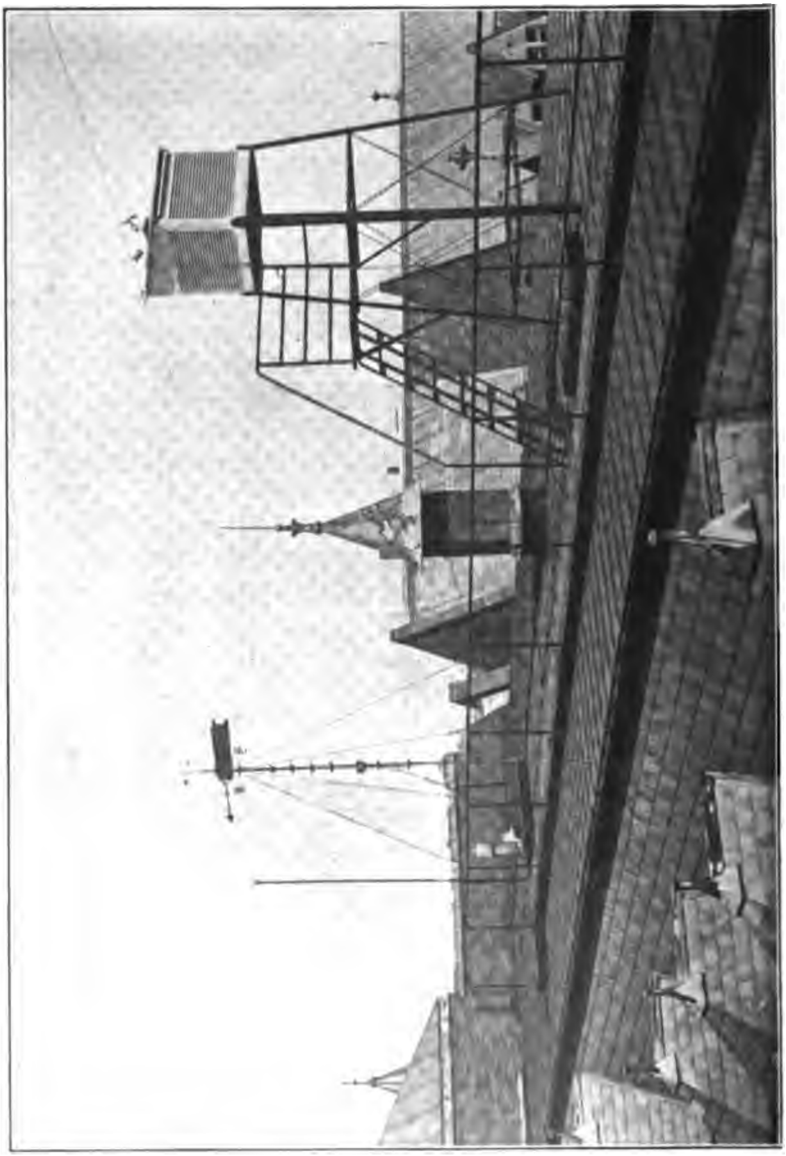
These are only a few of the many interesting notes, telling of the visits of earthquakes, storms, tornadoes, the aurora borealis, the migration of birds, etc.

THE NEW OBSERVATORY.

Some 36 years had to elapse before a favorable opportunity for re-establishing the observatory was met with. Meanwhile, the development of the University in its various departments had kept pace with the rapid growth of the city. The need of larger quarters and the encroachment of the business district had determined the authorities to abandon the old site at Ninth Street and Washington Avenue for a more suitable location. The outcome was the erection of the present group of modern buildings on Grand Avenue, Lindell and West Pine Boulevards.

That a Meteorological Observatory would be a valuable and perhaps necessary department in the general expansion of the University was readily conceded, but it was recognized likewise that, in view of the modern requirements of meteorology, none but the most complete and reliable equipment would form a useful investment. It was further desired that, if the observatory were re-established, it should be rather as a research laboratory than a station for gathering the ordinary weather data. The funds for carrying out this project were provided by friends of the University towards the close of the year 1909. A Meteorological Bureau of the first class was the established, and thereby long cherished hopes were realized. As soon as the instruments could be secured, the work of installing them began The roof of the Divinity Building, 76 feet above ground, was selected as the most advantageous location for the thermometers, wind vane, rain gauge, anemometer, etc. The exposure towards the residential district of the West End is particularly favorable. The proximity of the Administration and Arts and Science Buildings towards the east was found to exert no disturbing influence. The thermometer shelter is 86 feet, and the anemometer and wind vane 96 feet above ground. A cable carries the connections of the electrically recording instruments to the office room in the Arts and Science Building.

In the desire to begin official observations on January 1, 1910 those in charge of the observatory had to be content with a rather



INSTRUMENTS ON DIVINITY BUILDING.

inconvenient location for the recording instruments. It was only in September, 1910, that more suitable quarters were occupied, when one of the large physical laboratory rooms became vacant and was given over to the observatory.

Equipment.

The present equipment of the observatory consists of the following instruments:

1.) Fortin Barometer.
2.) Barograph, Richard Bros. pattern.
3.) Thermograph, Richard Bros. pattern.
4.) Maximum and Minimum Thermometers.
5.) Whirling Psychrometer.
6.) Hygrograph.
7.) Thermograph (National Clock and Electric Mfg. Co.).
8.) Tipping Bucket Rain Gauge.
9.) Snow Gauge.
10.) Electrical Sunshine Recorder.
11.) Jordan's Photographic Sunshine Recorder.
12.) Wind Vane.
13.) Anemometer (Robinson).
14.) Meteorograph (Quadruple Register).
15.) Ceraunograph (Lightning Recorder).
16.) Ceraunophone.
17.) Thermostatic and Temperature Alarm.
18.) Ground Thermometers.
19.) Several Standard Thermometers.
20.) Electrograph.

The instruments are of standard make and of United States Weather Bureau patterns.

SCOPE OF THE WORK.

The propriety of establishing a Meteorological Observatory as a department of a University may not be so obvious as to require no word of justification. As stated above, the purpose of the observatory is to conduct a research station. If our universities seek to promote the material welfare of the world by subsidizing and operating laboratories for research in agriculture, electricity, biology, medicine and a score of other sciences, why not, on the same plea, assume a like attitude toward the study of the weather? True, other sciences enable us to get in more direct contact with the forces of nature and to make them the servants of our necessities and pleasures, while the meteorologist, after all his probing into the laws governing the phenomena of our atmosphere, may be able to do little more than foresee weather conditions at a comfortable distance, without being able to offer further protection. Thus stated, the advantages offered may not seem worth the effort; but they assume tremendous proportions when measured in terms of property saved, health and lives preserved. If such be the nature and extent of the advantage to be gained, there should be no hesitation in giving meteorology its proper relation to the other sciences now fostered in our universities.

This position gains strength from the fact that meteorologists themselves, at least in this country, look to the universities for assistance in solving their larger problems. At the Peoria Convention of Weather Bureau Officials, Professor Cleveland Abbe said: "We have also to wish that the professors and special mathematical students interested in meteorology shall have their attention directed specifically to some of our problems; for instance, the mathematical expressions for the action of the wind on a plane surface. . . . But there are still grander problems for the mathematicians of the universities. I refer to the motions of the atmosphere and the attendant temperature and rainfall."

Some experts, such as Professor Langley, have been lending their assistance in this way. The truest response to Professor Abbe's suggestion, however, assumes the shape of liberal endowments, for the purpose of putting the work on a safe and independent footing. A gift of this sort has furnished this observatory with its preliminary equipment, and it is only with the help of similar gifts that the research work, for which it was principally established, can be carried on.

In recent years the teaching of meteorology has been taken up, in one way or another, by a very large number of High Schools, Colleges and Universities, and in some places even by the Primary Schools. The extent to which it is adopted and the methods employed differ so widely, however, that it may be well to state here what attitude St. Louis University has assumed.

The proper time to introduce the youth of this country to the elements of meteorology is evidently the High School period. In the three High Schools of St. Louis University elementary meteorology is an elective, with Tarr as a text book. In the College of Arts and

Sciences and in the School of Philosophy and Science, meteorology is taught only indirectly, the respective professors of the various courses in physics being permitted to use their own judgment as to the extent to which the application to this science of the principles of mechanics, heat, molecular physics, electricity and magnetism should be enlarged upon. This conservative attitude is dictated chiefly by a familiar circumstance, local as well as general. The average student interested in science is bent on investing the capital of his talents in projects that give promise of big dividends. From this point of view, meteorology as a profession offers no strong temptation. For the Weather Bureau service—by which alone at present, in the absence of endowed positions at our universities, any inducements are offered—admittedly does not bear comparison in point of remuneration with other occupations open to the prospective engineer or physicist.

The alternative, suggested by Professor Abbe on the occasion mentioned above as a means of making the most of this very actual condition, viz., to induce our students to take up some special meteorological problems as a side issue, is put into practice at St. Louis University in the following manner:

This observatory has a definite number of assistant positions which are open to capable applicants. Whilst incumbents are expected to do the routine work, and to be at the general disposal of the officials in charge, they are supplied with all books and equipment necessary to obtain a thorough knowledge of the principles of the science, are permitted to do observational work, and are given individual direction in their efforts. They are kept in close touch with recent developments, especially with the research work at the observatory. No fee is demanded. At present eleven students, mostly interns, are availing themselves of these opportunities to a greater or less extent. This same method is followed in the Department of Seismology, and it may be mentioned here that the majority of the assistants lend their help in both departments.

Whatever greater good may come of this method, this much is assured, that a large number of capable minds will have become sufficiently interested and experienced in the science to contribute, to the extent of their opportunities, some of the "bricks and mortar" of which the much desired result will eventually be built up.

This observatory heartily seconds the efforts made by the U. S. Weather Bureau officials to familiarize the general public with the main working principles of meteorology, and thereby to eradicate old superstitions and prejudices, and above all to hedge in the influence of illegitimate forecasters. With the exception of a daily bulletin issued for the perusal of intern students and members of the faculty, the observatory issues no forecasts.

THE CERAUNOGRAPH.

While the work of the past year has, of necessity, been chiefly constructional, we are pleased to be able to record some results achieved in at least one field of investigation. We have devoted considerable attention to the study of thunderstorms by way of perfecting the ceraunograph. The instrument is fairly well known in meteorological circles, but some account of the simplified form which we have given it may be of interest; and, as these lines are intended likewise for the uninitiated, we have thought it well to give a complete description of the instrument, as well as a brief elementary explanation of the principles involved.

That a means of predicting the approach of thunderstorms, hours in advance of their arrival, cannot fail to be of immense utility needs no comment. Everyone is aware that of the appalling loss of life and property occasioned by meteorological factors, by far the greater part falls to the account of the thundersquall and the tornado. These phenomena usually appear without much warning, and before we have time to seek shelter or to protect our goods we are overtaken by powerful and shifting gusts of wind, violent discharges of lightning, and frequently by a heavy downpour of rain and hail. It is the being caught unawares for which we must pay so dearly. Yet, until a very short time ago, we had no way of learning when to be on our guard. There was no practical or expeditious method of obtaining warning reports of these storms.

It was, therefore, a thoroughly welcome advance when it was discovered that thunderstorms give ample warning of their coming by means of powerful signals sent out broadcast, and a still greater step forward when an instrument was devised for intercepting these signals.

In a paper communicated to the Royal Society in 1867, and with greater completeness in his treatise on Electricity and Magnetism in 1873, Clerk Maxwell set forth his epoch-making theory of electromagnetism, suggesting therein that electro-magnetic effects travel through space in the form of transverse waves similar to those of light and having the same velocity. In 1888, conclusive experimental proof of this theory was found by Heinrich Hertz, of the University of Bonn, Germany, who succeeded in producing these electro-magnetic waves by means of an "oscillator." This instrument consisted of two metallic conductors between which an electric spark was permitted to pass. Hertz observed that the current "oscillated" or rocked back and forth between the conductors until equilibrium was obtained, very much as water when suddenly poured into a U tube will surge from one side to the other until it comes to rest. When the rapidity of these "oscillations" is made very high, some of the energy of the discharge is cast off into space and travels on in the shape of "electro-magnetic waves." A close analogy to this resulting action is the formation of ripples on the surface of a pond when a stone is thrown into it, except that the "electric ripples" spread out in all directions. These electro-magnetic or Hertzian waves, as they are now called, constitute the warning signals of the thunderstorm.

Naturally, Hertz's achievement attracted wide attention, and immediately a number of great minds, among whom Lodge and Branly were conspicuous, set themselves to the task of devising a practical means of detecting the passage of these waves. One of the products of their investigations was the "coherer." Into a tube partly filled with metal filings two conducting plugs are introduced and connected with the poles of a battery. Owing to a thin coating of dust or of rust on their surfaces these filings ordinarily offer a very high resistance to the passage of a current through them, but when an electric wave strikes the tube, they suddenly "cohere" and become conductive. A slight tap throws them back into their former state of high resistance, thus making them ready to record the next wave.

The "coherer" received its widest application in wireless telegraphy. As it was found, however, that Hertzian waves are produced by thunderstorms, meteorologists recognized that the new instrument might prove a highly valuable addition to their station equipment. In 1895 Popoff, of the Russian navy, obtained a record of a distant thunderstorm by means of a filing coherer placed in a circuit with a relay. With this start the development of the lightning recorder was taken up by Tommasina, Boggio-Lera, Lancetta, and by Fathers P. J. Schreiber, S. J., and J. Fényi, S. J., of the Kalocsa Observatory. In this country the pioneer work was done by Rev. F. L. Odenbach, S. J., Director of the Observatory at St. Ignatius College, Cleveland, O., who likewise gave his instrument the now accepted name "Ceraunograph."

The various types of ceraunograph now in use are much the same in general outline; they differ, however; in the form of "coherer" employed. Father Odenbach uses a coherer of his own invention. In place of the metal plugs of the filings coherer he substitutes two steel pins, placed parallel to each other and about an inch apart, and across these pins he lays several small sticks of graphite. The particles of graphite exhibit the same phenomena of resistance to the electric current and of coherence under the influence of Hertzian waves as the metal filings in the tube coherer. The pins are clamped to a strip of hard rubber by means of binding posts, and this strip in turn is attached to the base of a telegraph sounder which thus also serves as decoherer. Small paper discs are glued to the ends of the graphite rods to separate them from each other and prevent their being thrown off the pins by the decoherer. In the construction of the coherer, and with certain modifications in the arrangement of the other parts of the instrument, we have followed the very successful plan elaborated by Father Odenbach.

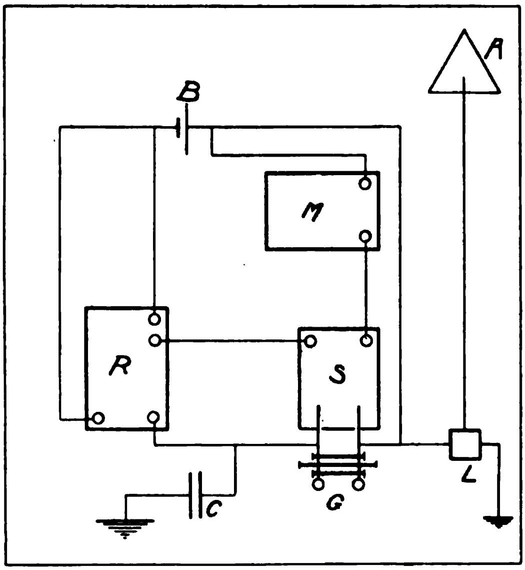


FIG. I

Our aerial consists of 900 feet of No. 10 bare copper wire stretched horizontally between the towers of the Divinity and Arts and Science Buildings and the high smokestack in the rear of the Philosophy Building. It forms an equilateral triangle, and at a point about 100 feet out over the Campus, a single strand leads away from the third angle to the Divinity tower. Leads are taken from the end at the Divinity tower and from the angle at the north tower of the Arts and Science Building. To guard against damage from high discharges through the wire, such as are occasionally caused by near-by lightning strokes, these leads are broken by a lightning arrester provided with a 2 or 4 ampere fuse. (Fig. 1) Beyond the arrester the aerial connection is introduced into the primary circuit of the instrument proper. This circuit passes through the graphite coherer, represented at *G*, and the relay *R*, and is operated by a single storage cell of 60 ampere hours capacity.

Between the coherer and the relay the aerial is grounded after passing through a fixed condenser *C*. The secondary circuit passes through the decoherer *S* and the recording magnet *M*, and is closed at the relay tongue. It has the same source of power as the primary circuit. The recording apparatus *M* is a single magnet register made by Friez, of Baltimore.

The successive steps in the operation of recording lightning discharges are briefly these: A wave or train of waves originating in the thunderstorm impinges on the aerial wire and descends on it into the primary circuit. At the coherer it finds the current ready to flow, but held in check by the resistance of the graphite. The wave transforms the graphite momentarily into a conductor, the current rushes through and operates the relay. The closing of the relay armature puts the secondary circuit into action; the sounder clicks, the magnet of the recorder closes and the pen makes a dash on the paper of the revolving drum. The very next moment the instrument is in readiness to record a second discharge, since the click of the sounder decoheres the graphite sticks and throws them back into their former state. The time required for the entire operation is, of course, only a small fraction of a second.

The above is a description of the ceraunograph in its essential form. In practice at this observatory four relays of different resistances are used, the desired one being thrown into the primary circuit by means of a four-point switch. Two of these relays, one of 1000 ohms, the other of 500 ohms, were made in our laboratory; the 250-ohm and 100-ohm instruments are of the ordinary type used in telegraphy. When the 1000-ohm relay is in operation we receive records of storms at Fort Worth, Tex.; Vicksburg, Miss.; Augusta, Ga.; Pittsburg, Pa.; Toledo, O.; Detroit, Mich., and Milwaukee, Wis., indicating a range of 500 miles or more. Throwing into the primary circuit one relay after the other and noting their relative activity enables us to determine at what distance from St. Louis the storm area is centered at any time of the day. Thus, if observations show that the maximum activity is gradually shifting from the 1000-ohm instrument to those of less resistance we know that the area is moving towards us and vice versa.

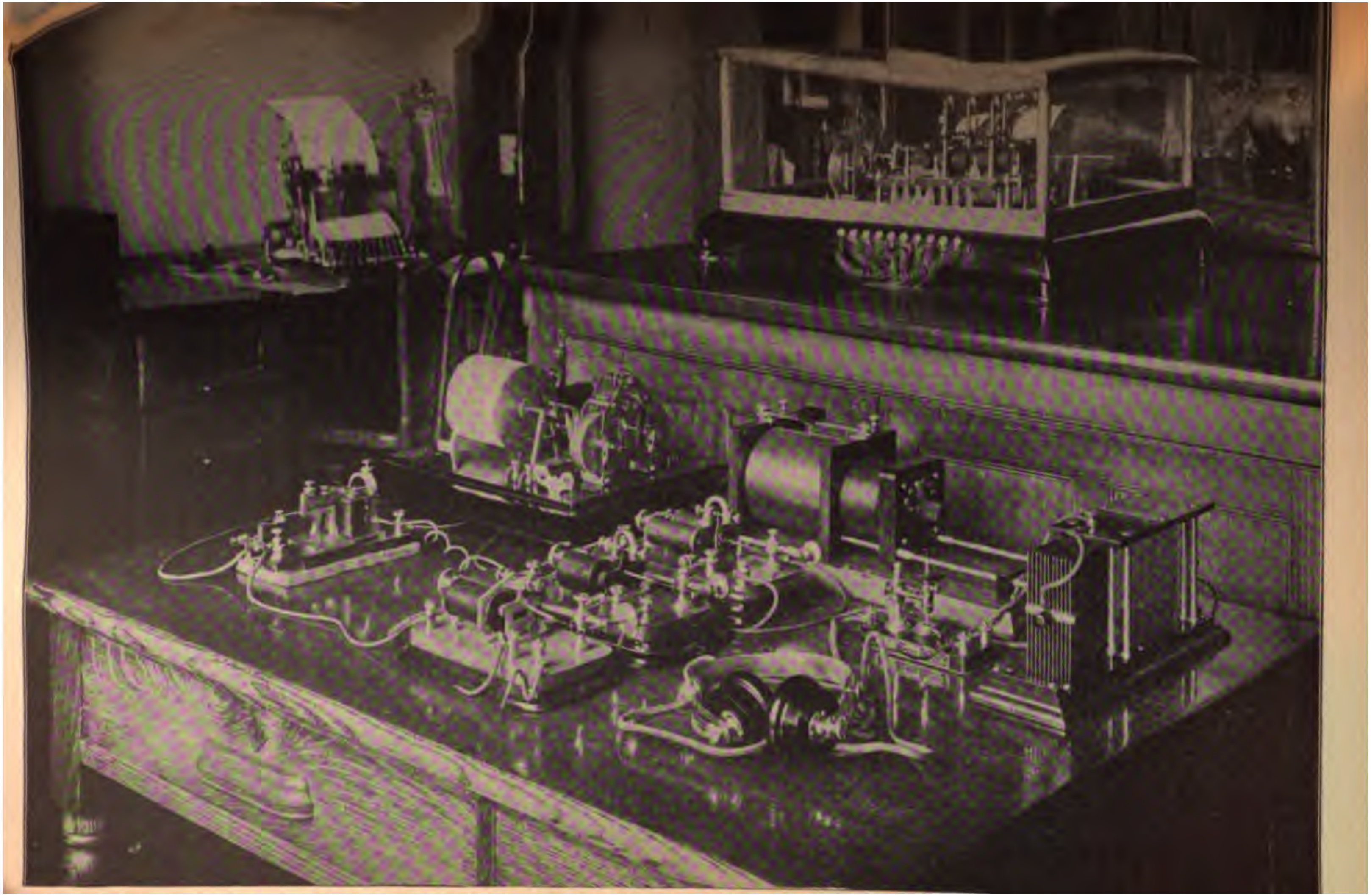
The sensitiveness of the coherer is regulated likewise by varying the number of sticks of graphite. Four are ordinarily used, but when the storm is overhead, the number is reduced to two. This ease of adjustment is one of the distinct advantages which the graphite coherer has over other types. What recommends it most, however, is its ready response to the decoherer.

The Branly radio-conductor, which forms the coherer of the ceraunograph at the Observatory of the Ebro, Spain, has a strong tendency to remain closed after a powerful discharge, resulting in the polarization of the battery and thus putting the instrument out of commission. The filings coherer also is inclined to become magnetized and must be laid aside. The graphite, on the other hand, becomes more effective with use. It must, however, be of a high grade. We have found A. W. Faber's "Siberian Leads for Artists' Pencils" (HHH No. 5900) highly satisfactory.

After the erection of the present aerial, in May, all of the 47 thunderstorms that passed over St. Louis up to January, 1911, were recorded by the ceraunograph. The instrument gave warning of their approach from 6 to 16 hours in advance. The severe storm at 7 P. M. on July 26 was picked up at the observatory 12 hours previously. Some disturbances, of course, especially heat thunderstorms, give much briefer warnings than those accompanying a "low," but the relative sensitiveness of the coherer, by betraying the electrical condition of the atmosphere, indicates just what probability exists for their occurrence.

A particularly happy change has been the placing of the condenser in its present position, for it has eliminated almost all possibility of non-decoherence, a very serious difficulty in the past. The danger has been further removed by using the same battery to actuate both circuits. This arrangement is also an important step towards the simplification of the instrument.

A cherished project, and one which promises to increase the efficiency of the instrument immensely, is the erection of a large umbrella aerial in place of the present horizontal one. By a peculiar manipulation of its various strands, about which it is too early to say



anything now, we hope to be able to learn, in addition to the distance, the direction of the storms from the observatory. When this has been done the last step will have been taken in the development of the ceraunograph on the principle now followed. For some time we have considered the installation of a revolving antenna such as is employed by the Jesuit Fathers at the Observatory of the Ebro, but have decided in favor of the umbrella aerial because of its greater ease of manipulation.

While we have no intention of using the ceraunograph in forecast work, that being outside of our scope, we are very anxious to see it reach a state of development where it can be installed and used with confidence and ease by all meteorological stations in the service of the public. We are confident, too, that this happy event is much desired by all who are aware of the destructiveness of unforeseen thunderstorms.

THE CERAUNOPHONE.

Wireless operators are familiar—sometimes disagreeably so—with the influence of thunderstorms on their instruments. Lightning discharges anywhere within range of the aerial are sure to make themselves heard in the receivers, and, as the waves they send out may be of varying lengths and are always very powerful, it is rather difficult to tune them out. But the ill wind has blown us good; for this very inconvenience suggested that a wireless receiving outfit would prove a splendid auxiliary to the ceraunograph.

In September of this year a first-class set of instruments made by Murdock, of Chelsea, Mass., was installed. Our expectations were fully realized when the single low-power receiver was discarded for a double head phone of 4000 ohms resistance. We were then enabled to explore the electric condition of the atmosphere far beyond the range of the ceraunograph. The receivers, under certain conditions, give better indications than the coherer of the intensity of a distant disturbance. We can always be sure about the adjustment of the ceraunophone, and thus have a reliable check on the more complicated working of the ceraunograph. The ceraunophone, of course, without written records can hardly supersede the ceraunograph in meteorological observations, for here the written record is essential, both for safe comparison from hour to hour and for future reference. As an auxiliary equipment, however, it possesses immense value.

A diagram of the arrangement of the instrument is given in Fig. 2. The loose coupled tuner *I* is in parallel with the variable condenser *C*, while the detector *D* is in series with the receivers. After considerable experimentation a silicon detector of the latest type was adopted as being most satisfactory for our purpose. The receivers have each a resistance of 2000 ohms.

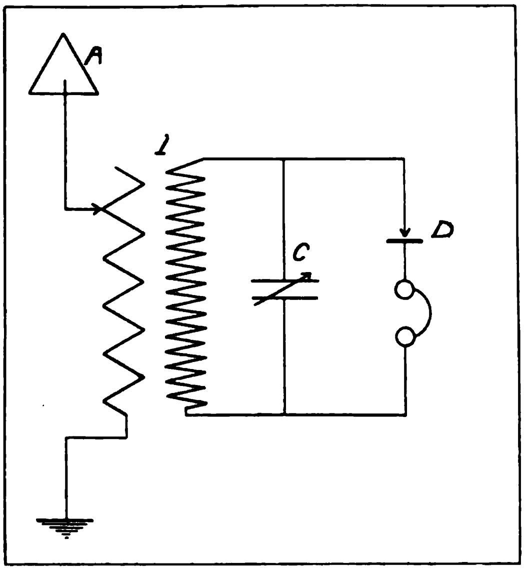


FIG. 2

JORDAN SUNSHINE RECORDER.

Another instrument added to the equipment of the observatory in the course of the present year is a Jordan Sunshine Recorder. A few remarks on the theory of this instrument will not be out of place in the present report, since the splendid treatise on the subject, published by the well known meteorologist, Rev. Julius Fényi, S. J., in 1891, may not be readily accessible to some of our readers. However, as the Reverend Author has given us his kind permission, we shall make liberal use of his work in our treatment of the subject.

The instrument consists of a hollow metal cylinder of radius 3.1 cm. and length 9.1 cm., so placed on an adjustable stand that its axis is parallel to the axis of the earth, and its two holes each 60° on either side of the meridian plane (*i. e.*, of the plane which passes

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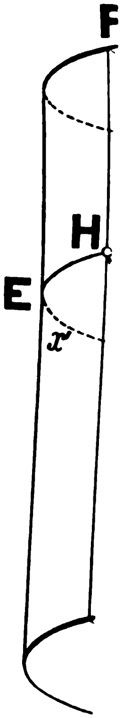

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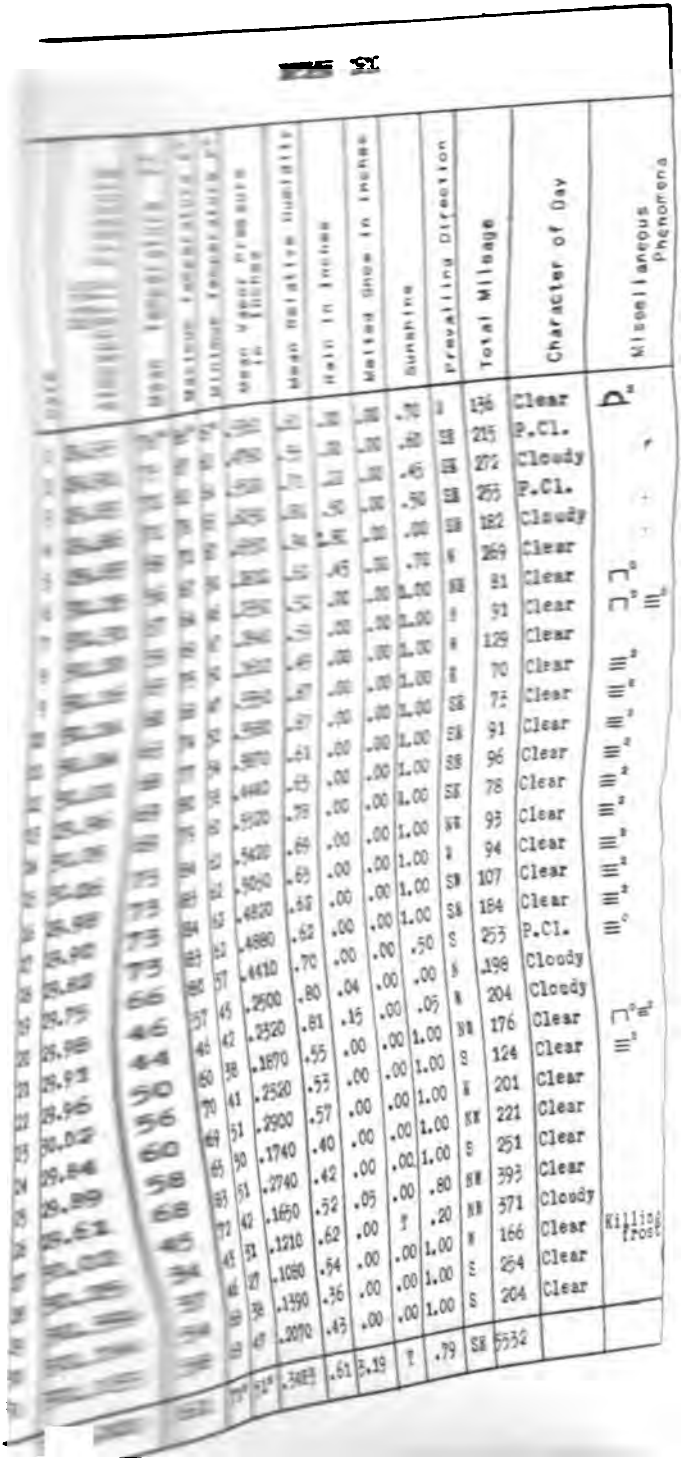

Date	[illegible]	Mean Temperature °F	Maximum Temperature °F	Minimum Temperature °F	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.70	[illegible]	136	Clear	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.60	SE	215	P.Cl.	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.45	SE	272	Cloudy	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.50	SE	255	P.Cl.	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.50	[illegible]	.00	SE	182	Cloudy	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.70	[illegible]	269	Clear	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.45	[illegible]	1.00	[illegible]	81	Clear	⊓²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	[illegible]	91	Clear	⊓² ≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	[illegible]	129	Clear	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	[illegible]	70	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	SE	73	Clear	≡¹
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.3970	.61	.00	.00	1.00	SE	91	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.4440	.65	.00	.00	1.00	SE	96	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.5020	.75	.00	.00	1.00	SE	78	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.5420	.69	.00	.00	1.00	NW	93	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.5060	.65	.00	.00	1.00	[illegible]	94	Clear	≡²
[illegible]	[illegible]	[illegible]	[illegible]	63	.4820	.62	.00	.00	1.00	SW	107	Clear	≡²
[illegible]	[illegible]	[illegible]	84	62	.4880	.62	.00	.00	1.00	SE	184	Clear	≡²
[illegible]	[illegible]	[illegible]	83	57	.4410	.70	.00	.00	.50	S	253	P.Cl.	≡⁰
[illegible]	[illegible]	[illegible]	57	45	.2500	.80	.04	.00	.00	[illegible]	198	Cloudy	
[illegible]	[illegible]	[illegible]	46	42	.2320	.81	.15	.00	.05	[illegible]	204	Cloudy	
[illegible]	[illegible]	[illegible]	60	38	.1870	.55	.00	.00	1.00	NE	176	Clear	⊓⁰≡²
[illegible]	[illegible]	[illegible]	70	41	.2520	.53	.00	.00	1.00	S	124	Clear	≡²
[illegible]	[illegible]	[illegible]	69	51	.2900	.57	.00	.00	1.00	W	201	Clear	
[illegible]	[illegible]	[illegible]	65	50	.1740	.40	.00	.00	1.00	NW	221	Clear	
[illegible]	[illegible]	[illegible]	83	51	.2740	.42	.00	.00	1.00	S	251	Clear	
[illegible]	[illegible]	[illegible]	72	42	.1650	.52	.05	.00	.80	NW	393	Clear	
[illegible]	[illegible]	[illegible]	45	51	.1210	.62	.00	T	.20	NE	371	Cloudy	
[illegible]	[illegible]	[illegible]	46	27	.1080	.54	.00	.00	1.00	[illegible]	166	Clear	Killing frost
[illegible]	[illegible]	[illegible]	[illegible]	38	.1390	.36	.00	.00	1.00	E	254	Clear	
[illegible]	[illegible]	[illegible]	[illegible]	47	.2070	.43	.00	.00	1.00	S	204	Clear	
[illegible]	[illegible]	[illegible]	73°	51°	.3483	.61	3.19	T	.79	SE	5532		

NOVEMBER 1910

Maximum Temperature	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Peevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
70°	44°	.2610	.55	.00	.00	.30	S	299	Cloudy	
47	33	.1067	.47	.00	.00	.95	NW	237	P.Cl.	
44	28	.0990	.49	.00	.00	1.00	N	129	Clear	$\equiv^{2}$
40	35	.1450	.63	T	.00	.00	SE	267	Cloudy	
46	37	.1330	.55	T	.00	.50	NW	259	P.Cl.	
56	29	.1200	.47	.00	.00	1.00	W	136	Clear	
68	38	.1860	.46	.00	.00	1.00	W	167	Clear	
60	41	.1980	.55	.00	.00	.80	SE	209	Clear	
74	52	.3320	.56	.00	.00	.70	S	251	P.Cl.	
68	38	.1470	.59	.00	.00	.80	NW	306	Clear	
42	32	.0955	.47	.00	.00	1.00	NW	214	Clear	
41	29	.1170	.57	.00	.00	.00	SE	119	Smoky	
48	35	.1260	.49	.00	.00	.00	SE	220	Cloudy	
45	38	.1390	.56	.00	.00	.80	NW	324	P.Cl.	
39	33	.1280	.68	.00	.00	.00	N	188	Cloudy	
40	28	.1150	.65	.00	.00	.00	NW	127	Cloudy	
40	26	.1370	.72	.00	.00	.80	NW	65	Clear	$\equiv^{2}\sqcap^{2}$
50	28	.1290	.50	.00	.00	.50	W	100	P.Cl.	$\sqcap^{2}$
47	27	.1390	.68	.00	.00	.80	NE	105	Clear	$\sqcap^{2}$
54	31	.2000	.76	.01	.00	.70	SE	191	P.Cl.	$\equiv^{0}\sqcap^{1}$
51	36	.2060	.74	.00	.00	.95	W	131	Clear	
52	29	.1680	.65	.00	.00	1.00	SE	214	Clear	$\equiv^{2}\sqcap^{2}$
59	47	.1690	.43	.00	.00	1.00	NW	227	Clear	
65	44	.1810	.39	.00	.00	1.00	NW	261	Clear	
56	38	.1600	.48	.00	.00	.50	NW	149	P.Cl.	
53	43	.2670	.72	.02	.00	.05	SE	315	Cloudy	⊕
65	39	.3300	.86	.16	.00	.05	NW	293	Cloudy	⊕ $\equiv^{0}$ T↯
39	25	.1233	.76	.00	.00	.95	NW	325	Clear	
34	25	.1140	.68	.00	.00	.70	NW	220	P.Cl.	
31	22	.0748	.56	.00	.00	1.00	NW	447	Clear	
50°	34°	.1617	.59	.19	.00	.63	NW	6291		

through the zenith, the celestial poles, the axis of the cylinder and the axis of the earth).

We are to find a simple equation, which will permit us to determine the time corresponding to a given point in the curve traced on the sensitive film by the pencil of solar rays penetrating into the cylinder through one of the holes. This we might do by determining the locus of the recording point with respect to space co-ordinates. It would evidently be an ellipse formed by the intersection of a variable plane with the cylinder. A simpler plan, however, and one equally accurate, will be the following: Figure 4 is a copy of a record obtained on the photographic film which is placed on the interior surface of the cylinder. H and H' are two holes in the film which coincide with the two holes in the cylinder. By properly choosing the position of plane Cartesian co-ordinates, we can obtain an equation in terms of known quantities which will satisfy the given locus

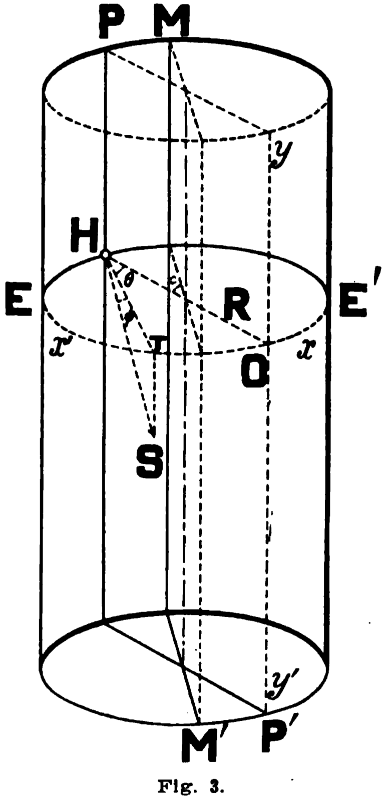

Fig. 3.

when the record is flattened out for examination as in Fig. 4. Through the cylinder we pass three planes, one EE' perpendicular to the cylinder and cutting the center of the hole H; another PP' through the axis and the hole H; the third MM' through the axis and coinciding with the plane of the local meridian. (See Figure 3.)

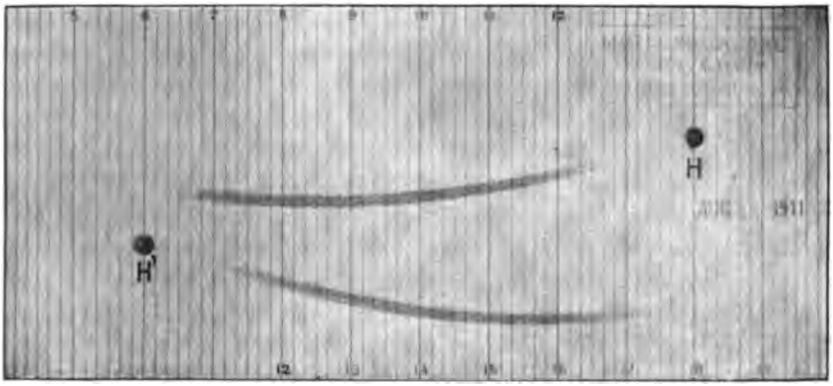

Fig. 4.

For the origin of co-ordinates we shall select the point O diametrically opposite to the hole H. The line of intersection of the plane EE' with the cylinder we shall make the axis of abscissæ xx'; and the line of intersection of the plane PP' with the cylinder will be the axis of ordinates yy'.

Now a ray of sunlight entering the cylinder at H will follow some path HS and impinge on the film on the opposite interior surface. The projection of this path on the plane EE' will be $HT = HO \cos \theta$, (since HTO is a right angle, being inscribed in a semicircle) $= 2R \cos \theta$, where R is the radius of the cylinder and θ the angle between HO and HT. Furthermore, the path HS makes a certain angle ϕ with its projection HT. The tangent of this angle is given by ST/HT. Hence $ST = HT \tan \phi$. Now ST is the ordinate of the point S, hence we may write $y = HT \tan \phi$ (2). But HT we have shown to be equal to $2R \cos \theta$ from (1), the angle ϕ is the angle of declination, D, of the sun, since EE' is parallel to the equatorial plane. Substituting these values in (2), we obtain: $y = 2R \cos \theta \tan D$ (3). Again, θ, being inscribed in a semicircle, is measured by half the subtending arc OT. But in radians $OT = OT/R = x/R$, since we agreed to call the line of intersection of EE' with the cylinder the axis of abscissæ. Hence angle $\theta = x/R \div 2 = x/2R$. Substituting in (3) we have our equation $y = 2R \cos x/2R \tan D$ (4).

The same reasoning and the same equation will hold for the other hole H' in the cylinder, and it remains only to find at what time of day $x = 0$, or when the sun will be in the plane PP'. Since the sun, no matter what its declination, passes over approximately equal meridian angles or the same number of degrees of longitude in equal intervals of time (15° per hour), $d\theta/dt = k$. And since θ is always an inscribed angle, it follows that $dx/dt = k'$. Therefore, given that the angle o between the planes PP' and MM' is 60°, $60 \div 15 = 4$ will give the number of hours before or after apparent noon when the sun will be in the plane PP' and $x = 0$; that is, at 8 A. M. or 4 P. M. It follows from this consideration that if we divide off the record by a system of parallel straight lines, equally spaced, the perpendicular distance across them will be proportional to the time and, if the space between the lines is so chosen as to correspond to one hour, the time of day can be read directly from the record. The value of this hour space may be obtained as follows from the relations shown above: Since $\theta_h = x_h/2R$, $x_h = 2R\theta_h$. Or, as θ_h (the angle passed over by the sun in one hour) $= \pi \div 12$, $x_h = \pi R \div 6$. Hence the beginning and the end of the Sunshine record or the passing of a cloud can be accurately timed. However, it must be noted that the actinic effect of the sun's rays for about one-half hour after sunrise and the same length of time before sunset is too weak to record photographically in this way.

GROUND TEMPERATURE.

On March 1, 1910, observations of ground temperature at a depth of 5 ft. below the surface were begun at this observatory. We were led to undertake these observations by a consideration of the interesting and valuable results obtained through them by a number of observers in various parts of the world.

The measurement of ground temperature is a very simple matter. In the small garden adjoining the Philosophy and Science Building two sections of 3 in. hard drainage tile were sunk into the ground. A few inches below the surface, the upper section, which has a movable cap, projects into a six-inch crock, the bottom of which has been removed. This crock is provided with a close-fitting lid, and is entirely covered by a small wooden tub. This triple covering effectively protects the shaft from the disturbing influence of solar radiation and atmospheric temperature. thus insuring true values for the temperature at the bottom of the shaft. The thermometer is suspended from the cap of the tile by means of a chain. The thermometer bulb was wrapped in asbestos paper to provide insulation from the atmospheric temperature while the reading is taken. In practice, however, the shaft never remains open more than about five seconds, the time required to make a single observation.

To explain the chief purpose of this branch of our work is a task which we reserve for a future publication.

Location of Observatory.

Latitude: 38° 38′ 17″ north.

Longitude: 90° 13′ 58″.5 west.

Elevation: 578 ft. above sea level.

Wind Vane: 94 ft. above ground.

Anemometer: 96 ft. above ground.

Top of Rain Gauge: 80 ft. above ground.

Floor of Thermometer Shelter: 10 ft. above roof and 86 ft. above ground.

Explanation to Meteorological Summaries.

Atmospheric Pressure in inches reduced to mean sea level.

Mean Temperature: the mean of three daily observations.

Mean Vapor Pressure and Mean Relative Humidity: the mean of the three daily readings of the various thermometers reduced according to the method used by the U. S. Weather Bureau.

Signs used for Miscellaneous Phenomena: The International Meteorological Symbols.

The official day ends with 7:00 P. M., except for wind velocity and direction, which end at 12:00 midnight.

THE WEATHER OF 1910.

January, 1910.

Temperature and precipitation were about normal. A heavy fall of rain and sleet on the 4th, followed by freezing temperature—the lowest of the month—on the 5th and 6th, blocked traffic and caused much suffering among the poor. The snowfall was light, one inch falling on the 30th. There were no sudden or extreme changes in temperature.

February, 1910.

The month of greatest snowfall in the history of local weather conditions. A low pressure from the Southwest on the 9th brought 5 inches, the blizzard on the 16th, 13.8 in.—the heaviest fall in 25 years—and smaller amounts scattered through the month, brought the total up to 20.6 in. The mean temperature, 29°, was 5° below the normal. On the 18th the lowest temperature of the year, —2°, was recorded. In the suburbs —15° was reported.

March, 1910.

The driest and warmest March in 50 years. The precipitation amounted to only .14 in., and more than half of this fell on the 30th. The smallest amount previous to this occurred in 1860 with .33 in.—the normal for this month being 3.3 inches. There were 22 clear days and only 2 cloudy days, and the average daily sunshine was 86.7%, the largest percentage ever recorded here. The mean temperature for the month 57°.5 was no less than 13°.5 above the normal. On seven successive days, from the 22nd to the 29th, the mercury rose above 80°, reaching 89° on the 23rd. The temperature was at freezing point only three times, but never lower. This abnormally warm weather was largely due to the fact that the centers of storm areas during the month almost invariably passed north of the city, most of them along the Canadian border, thus inducing prevailing winds from the Gulf and the plains of the Southwest.

April, 1910.

Extreme changes in temperature and a very destructive frost late in the month were the features of the weather during April. The maximum, 91° on the 29th, was exceeded only twice before, 93° having been recorded in 1855 and 1866. The period from the 23rd to the 26th was a ruinous one for almost all vegetation in this region. A tramp "low," hanging over the Lake region for three full days, brought on a killing frost on the 23rd; on the 24th the minimum temperature of 25°, the absolute minimum for the 3rd decade in April, together with an unseasonable, heavy snowfall of 2.5 in. The precipitation was 1.16 in. above the normal. Measurable amounts fell on 17 days. There were 5 thunderstorms during the month.

May, 1910.

The warm period with which April closed extended over into May for a few days. During the rest of the month, however, the temperature was abnormally low for the season. The mean for the month 61°, was 5° below the average. The mercury reached the 80° mark only four times and on half the days of the month did not rise above 65°. Rain occurred on 15 days, the largest number in May for over 20 years. The total precipitation was 5.35 in., almost an inch above the normal amount. On the night of the 22nd to the 23rd 2.12 in. fell within 12 hours. Seven thunderstorms passed over the city, one of them causing considerable damage in the suburbs on the morning of the 2nd.

June, 1910.

The first decade of the month was decidedly cool, the mean daily temperature being constantly below 70°. Of the 5.20 in. of rain which fell during the month, 3.47 in. arrived during the first period. High temperatures prevailed during the rest of the month, however, the mean after the 14th being almost constantly above 80°. On nine consecutive days, from the 18th to the 26th, the maximum temperature was at or above 90°; on the 26th it reached 93°. The fact that on some of the days the movement of the wind was only four miles an hour made the heat all the more noticeable. There were 10 thunderstorms during the month.

July, 1910.

An examination of the temperature records for July would make it appear that the month was comparatively cool—the mean being 78°, one degree below the normal, the maximum 90° on only six days —but the high relative humidity detracted much from its agreeableness. The rainfall, too, was excessive, the total 6.01 in. being 2.37 in. above the average. This amount was distributed over 13 days and most of it came with thunderstorms, of which there were 10 during the month. At 7 P. M. on the 25th the most severe thundersquall of the year struck the city from the Northwest, its path lying directly over the observatory. The wind reached a maximum velocity of 60 miles an hour, and 1.10 in. of rain fell within 12 hours. The day had been very hot, its maximum 96° being the highest recorded during the month. Within half an hour the temperature dropped from 94° to 65°.

August, 1910.

The temperature exceeded 90° on only six scattered days, reaching 94° on the 30th. The mean was 75°.7, whereas the normal is 78°. Appreciable amounts of rain fell on 7 days, making a total of 1.92 in.; the average quantity for August is 2.44. As in the preceding month, the relative humidity was high, and fogs and heavy dew were frequent. Five thunderstorms passed over the city and three others occurred in the immediate vicinity, but none of them were violent

On the 23rd the ground temperature reached its annual maximum, 68°.

September, 1910.

With no well-defined distribution of atmospheric pressure, heavy showers occurred on the 4th of the month, creating the year's record for maximum precipitation within 24 hours. The total for the day was 3.64 in. In all 5.61 in. of rain fell during the month, whereas the normal amount for September is 3 in. The mean temperature, 71°, was 1° above the average. Small ranges in temperature and plenty of sunshine—63%—were responsible for the general agreeableness of the month.

October, 1910.

Twenty-three clear days, an average daily sunshine of 79%, and a mean temperature of 2°.5 above the normal are evidences of the very pleasant weather which prevailed during October—St. Louis' favorite month. The rainfall, indeed, exceeded the normal amount by almost an inch, but by far the greater portion fell within the brief period from the 3rd to the 6th. On the 5th 1.80 in. fell within 24 hours. The first killing frost delayed until the 29th, although there had been a heavy frost a week previous. The first snow fell on the afternoon of the 28th, but the amount was not measurable. No thunderstorms occurred during the month.

November, 1910.

November was a close rival of March in the matter of clear, dry weather. As in March, there were only three days on which appreciable amounts of precipitation occurred, and the total was only .19 in., of which .16 in. fell during a thunderstorm on the 27th. With the exception of November, 1865, when the total precipitation was only .08 in., this is the driest November on record since 1839. Normally almost 3 in. fall during this month. There was not even a trace of snow during the entire month. Without any decided extremes, the temperature was low; the mean, 42°.5, was 2°.5 below the normal. The thermometer registered higher than 60° on only 6 scattered days, and failed to reach 50° on half the days of the month.

December, 1910.

Freezing weather was practically uninterrupted throughout the month, the mean being 32°.5, about 3° below normal. The minimum temperatures, however, were not unusually low. Precipitation was about 1 in. below the average amount. The total snowfall was 2.20 in.

JANUARY 1910													
Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.90	46°	61°	58°	.2950	.93	.00	.00	1.00	S	148	Clear	≡^{2}
2	30.14	27	41	25	.1210	.84	.00	T	.00	NW	131	Cloudy	
3	30.52	22	29	20	.0789	.67	T	T	.05	N	250	Cloudy	Sleet
4	30.34	21	26	15	.0922	.89	.08	.04	.00	SE	282	Cloudy	Sleet
5	30.23	18	32	15	.0702	.74	.75	.00	.45	NW	214	Cloudy	Sleet
6	30.28	8	15	3	.0442	.76	.00	.00	.00	NW	169	Cloudy	
7	30.33	23	33	10	.0958	.76	.00	.00	1.00	SE	144	Clear	
8	30.40	32	38	24	.0990	.55	.00	.00	1.00	S	144	Clear	
9	30.68	21	35	17	.0723	.67	.00	.00	.63	N	142	P.Cl.	
10	30.61	27	34	17	.0910	.67	.00	.00	.78	SE	303	Clear	
11	30.47	38	41	29	.1370	.60	T	.00	.00	SE	160	Cloudy	
12	30.34	39	41	36	.2070	.89	1.32	.00	.00	S	167	Cloudy	≡^{2}
13	30.18	37	45	32	.2050	.90	.45	.00	.00	NW	281	Cloudy	
14	30.42	30	34	27	.1190	.72	.00	.00	.20	NW	318	Cloudy	
15	30.50	28	31	26	.1210	.82	.00	.00	.00	SE	165	Cloudy	
16	30.25	31	33	28	.1670	.96	.06	.00	.00	SE	251	Cloudy	
17	29.72	47	54	53	.3010	.93	.07	.00	.00	SE	214	Cloudy	
18	29.93	37	55	31	.1690	.77	.08	.00	1.00	W	314	Clear	
19	30.06	47	58	37	.1990	.61	.00	.00	1.00	N	178	Clear	◒
20	29.97	39	58	34	.1820	.81	.00	T	.04	NE	377	Cloudy	
21	30.03	27	35	24	.0825	.60	.00	.00	1.00	NW	476	Clear	Comet seen
22	29.85	28	36	15	.0783	.57	.00	.00	1.00	NW	237	Clear	
23	29.83	39	44	35	.1750	.69	.00	.00	1.00	NW	159	Clear	
24	30.15	30	40	27	.1390	.84	.00	.00	.60	NW	102	P.Cl.	
25	29.85	40	49	30	.1700	.70	.00	.00	1.00	N	380	Clear	
26	29.56	49	58	46	.1830	.54	.00	.00	1.00	SE	488	Clear	
27	29.86	37	47	31	.1570	.75	.00	.00	.90	NW	246	Clear	⊕ ◒
28	29.71	35	40	26	.1430	.71	.00	.00	1.00	NW	149	Clear	⊓^{2}
29	29.90	32	39	30	.1480	.83	.00	T	.00	NE	132	Cloudy	
30	30.04	24	33	19	.0953	.78	.00	.10	.70	NW	222	P.Cl.	
31	30.23	24	29	18	.0994	.79	.00	.00	.60	SE	172	P.Cl.	
	30.14	32	40°	25°	.1399	.75	2.81	.14	.51	NE	7115		

FEBRUARY 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.12	37°	48°	26°	.1590	.74	.00	.00	.80	S	292	Clear	$\sqcap^0$
2	29.93	47	54	41	.2680	.84	.05	.00	.30	SE	194	Cloudy	
3	30.24	32	45	31	.1580	.85	.32	.05	.30	NW	268	Cloudy	
4	30.27	34	43	24	.1510	.79	.00	.00	1.00	W	208	Clear	$\sqcap^2$
5	30.11	35	44	28	.1240	.66	.00	.00	.80	NW	149	Clear	$\sqcap^2$
6	30.44	23	35	17	.0725	.61	.00	.00	1.00	N	162	Clear	
7	30.29	31	36	22	.0953	.58	.00	.00	.80	SE	207	Clear	
8	30.05	40	49	33	.1610	.69	.00	.T	.90	NW	184	Clear	
9	30.14	28	39	26	.1068	.71	.00	.45	.60	NW	245	P.Cl.	
10	30.28	29	38	17	.1124	.72	.00	.00	1.00	SE	129	Clear	$\sqcap^2$
11	30.11	35	40	30	.1217	.63	.00	.00	.40	SE	147	Cloudy	
12	30.17	19	35	12	.0623	.65	.00	.03	.90	NW	372	Clear	
13	30.30	29	39	16	.1080	.67	.00	.00	.90	W	213	Clear	
14	29.90	45	58	34	.1540	.50	.00	.00	.95	S	264	Clear	
15	29.66	53	64	42	.2550	.61	T	.00	.30	N	365	Cloudy	Sleet
16	30.23	17	45	16	.0785	.89	.00	1.15	.00	N	335	Cloudy	
17	30.28	8	16	5	.0476	.81	.00	.23	.05	NW	341	Cloudy	
18	30.35	12	22	-2	.0528	.56	.00	.00	1.00	SE	236	Clear	$\equiv^1$
19	30.27	23	33	9	.0739	.64	.00	.00	1.00	SE	277	Clear	⊖
20	29.86	34	40	22	.1416	.69	T	.00	.00	SE	313	Cloudy	
21	30.06	27	39	25	.1160	.79	.00	.03	.00	N	225	Cloudy	
22	30.22	25	28	19	.1099	.81	.00	.07	.30	NW	171	Cloudy	Frozen fog
23	30.61	4	28	-1	.0247	.55	.00	.00	.07	N	237	Cloudy	C.W.
24	30.55	16	24	3	.0415	.47	.00	.00	1.00	N	152	Clear	
25	30.24	29	37	16	.0921	.55	.00	.00	.85	SE	282	Clear	⊕
26	29.91	42	43	38	.2410	.91	1.03	.00	.00	SE	242	Cloudy	
27	30.05	31	43	27	.1203	.67	.00	.00	.70	NW	211	P.Cl.	
28	29.99	33	40	27	.1470	.79	.00	.00	.85	SE	184	Clear	$\equiv^2$
	30.17	29'	39^8	21^6	.1213	.69	1.40	2.01	.60	SE	6606		

MARCH 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.97	44°	51°	33°	.2360	.75	.01		.49	SE	162	Cloudy	$\equiv^2$
2	30.07	54	70	33	.2420	.61	.00		1.00	W	142	Clear	$\equiv^2$
3	30.10	56	65	44	.2500	.59	.00		1.00	SE	159	Clear	
4	29.98	65	76	49	.2920	.51	.00		1.00	W	119	Clear	
5	29.88	70	80	57	.2950	.43	.00		.70	SE	155	P.Cl.	
6	30.02	57	74	50	.1720	.39	.00		.95	NW	332	Clear	
7	30.06	47	56	36	.1270	.40	.00		1.00	NW	298	Clear	
8	29.94	47	55	37	.1670	.54	.00		1.00	N	139	Clear	
9	30.11	38	50	34	.1520	.69	.00		.00	N	140	Cloudy	
10	30.18	39	46	32	.1014	.43	.00		.81	N	177	Clear	
11	30.02	47	60	31	.1590	.51	.00		1.00	N	199	Clear	$\sqcap^2$
12	30.15	46	55	36	.1680	.58	.00		.93	NW	155	Clear	
13	29.98	58	67	47	.1860	.44	.00		1.00	N	283	Clear	
14	30.26	38	54	35	.1134	.51	.00		1.00	N	260	Clear	
15	30.26	39	48	27	.1031	.47	.00		1.00	W	90	Clear	
16	30.00	55	66	38	.1570	.38	.00		1.00	NW	224	Clear	
17	30.05	56	66	41	.1430	.37	.00		1.00	NW	105	Clear	
18	30.11	60	71	48	.2390	.45	.00		.85	SE	103	P.Cl.	
19	30.07	63	72	52	.2870	.52	.00		1.00	SE	157	Clear	
20	30.06	63	71	55	.3360	.59	.05		1.00	N	217	Clear	Ʈ
21	30.12	56	69	36	.2320	.51	.00		1.00	SE	157	Clear	
22	29.90	74	86	57	.2860	.37	T		.75	E	188	P.Cl.	
23	29.93	75	69	57	.2970	.41	.00		1.00	SE	122	Clear	
24	29.94	76	87	63	.2700	.31	.00		.70	W	204	P.Cl.	
25	30.10	72	80	61	.2070	.27	.00		1.00	SE	203	Clear	
26	29.91	71	80	61	.3180	.43	.00		1.00	SE	204	Clear	
27	29.91	76	87	61	.2490	.31	.00		1.00	SW	217	Clear	
28	30.00	75	86	64	.2800	.33	.00		1.00	SE	212	Clear	
29	29.94	72	79	63	.3870	.50	.00		.60	SE	310	P.Cl.	$\equiv^1$
30	30.04	66	79	58	.3630	.57	.08		.50	NW	330	P.Cl.	
31	30.27	56	63	47	.2010	.48	.00		.60	NW	126	P.Cl.	
	30.04	58^4	69	46	.2264	.47	.14	00	.87	SE	6168		

APRIL 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.19	61°	70°	49°	.2020	.40	.00		1.00	NW	94	Clear	
2	30.01	63	71	55	.3150	.55	.10		.30	SE	165	Cloudy	☈3PM
3	29.81	64	72	56	.4540	.76	.17		.00	SE	251	Cloudy	
4	29.77	68	72	65	.4410	.63	.03		.00	SE	275	Cloudy	☈7PM
5	29.61	51	68	41	.3080	.76	1.21		.50	W	380	Cloudy	☈ ▲10AM
6	29.92	51	55	39	.1950	.54	T		.60	NW	309	P.Cl.	
7	30.09	57	61	41	.2090	.48	.00		.88	SE	122	Clear	
8	30.06	66	78	50	.2810	.46	.00		.72	SE	116	Clear	
9	30.10	68	76	56	.2800	.44	.00		1.00	NW	115	Clear	
10	30.00	69	79	56	.3040	.45	.00		1.00	SE	180	Clear	
11	29.77	62	73	59	.4390	.78	.14		.30	SE	180	Cloudy	
12	29.86	55	60	51	.3350	.77	.04		.30	N	231	Cloudy	
13	29.98	61	70	47	.2350	.45	.00		1.00	SE	116	Clear	
14	29.76	66	76	54	.3830	.60	.15		.67	SE	323	P.Cl.	☈ Δ7PM
15	29.64	67	77	58	.5000	.78	1.11		.46	N	176	P.Cl.	☈ 6PM
16	29.67	42	66	37	.2020	.77	.93		.00	NW	255	Cloudy	
17	29.69	40	42	37	.1730	.70	.05		.07	W	241	Cloudy	
18	29.83	36	40	31	.1700	.81	.04	.05	.00	NW	319	Cloudy	Δ^1
19	29.98	43	52	37	.2080	.73	.01		.30	NW	344	Cloudy	
20	29.94	51	63	37	.2030	.55	T		1.00	NW	206	Clear	⊓°
21	29.77	63	71	47	.2720	.48	.00		.66	SE	259	P.Cl.	
22	29.69	58	72	47	.3100	.63	.10		.14	W	335	Cloudy	
23	29.87	32	34	28	.1260	.72	.00	.05	.00	NW	363	Cloudy	Killing Frost
24	29.93	33	38	25	.1170	.64	.00	.25	.18	N	251	Cloudy	" "
25	29.96	40	44	32	.1820	.77	.00		.02	N	213	Cloudy	
26	29.82	45	49	37	.2190	.76	.18		.12	NW	273	Cloudy	
27	30.02	60	68	46	.2910	.58	.01		1.00	N	225	Clear	
28	29.98	70	84	50	.3060	.45	.00		1.00	SE	198	Clear	
29	29.68	79	91	62	.2080	.36	.00		1.00	S	260	Clear	⊕
30	29.73	76	86	68	.3690	.41	.00		.80	SE	189	Clear	
	29.87	56°	65°	46°	.2779	.60	4.27	.35	.50	SE	6864		

MAY 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction—	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.83	66°	78°	55°	.4500	.69	.18		.21	SE	144	Cloudy	☈ 9:35
2	29.89	65	82	55	.4790	.80	1.07		.35	N	285	Cloudy	3AMA $\equiv^{2}$
3	30.28	51	58	43	.2440	.66	.34		.21	N	246	Cloudy	
4	30.35	53	60	40	.1980	.50	.00		.74	NE	117	P.Cl.	
5	30.30	55	60	43	.1940	.45	.00		.60	SE	178	P.Cl.	
6	30.08	52	59	49	.2480	.65	.12		.00	E	240	Cloudy	
7	29.65	51	55	47	.3070	.84	.50		.00	SE	294	Cloudy	☈ dn
8	29.76	51	56	45	.2950	.80	.02		.00	W	236	Cloudy	$\equiv^{1}$
9	29.92	68	78	50	.3160	.48	.00		1.00	W	193	Clear	
10	29.87	71	78	59	.4200	.56	.03		.64	SE	114	P.Cl.	☈AM and PM
11	29.77	60	73	55	.4470	.89	.30		.07	N	251	Cloudy	☈
12	30.11	56	63	46	.2210	.52	.00		1.00	NW	222	Clear	Red Moon
13	30.16	57	64	43	.1900	.43	.00		1.00	NW	191	Clear	" "
14	30.17	58	64	49	.1880	.40	.00		.76	SE	174	Clear	$\equiv^{0}$
15	30.07	56	62	50	.2450	.58	.02		.08	SE	294	Cloudy	◓
16	29.99	63	67	51	.4040	.72	.05		.35	SE	300	Cloudy	
17	29.94	63	66	50	.3460	.63	.26		.50	NW	310	P.Cl.	☈ dn ◒
18	30.04	66	75	50	.2890	.49	.00		1.00	SE	167	Clear	◒
19	29.84	68	76	56	.3700	.55	T		.50	SE	216	P.Cl.	
20	29.67	75	86	62	.4690	.61	.07		.86	SE	186	Clear	
21	29.76	72	77	65	.5490	.69	T		.50	SE	213	P.Cl.	
22	29.77	66	73	60	.5230	.82	.18		.14	SE	187	Cloudy	
23	29.76	62	65	60	.4470	.82	2.12		.04	NW	243	Cloudy	
24	29.76	65	70	56	.2980	.50	.00		.94	NW	198	Clear	◓
25	29.98	64	70	51	.2640	.45	.00		.95	NW	172	Clear	
26	30.09	67	72	56	.3130	.48	.00		.62	NE	103	P.Cl.	
27	30.26	61	66	54	.2750	.51	T		.21	SE	233	Cloudy	
28	30.15	73	82	58	.3980	.50	T		1.00	SE	312	Clear	
29	30.04	73	80	65	.4000	.52	.09		1.00	NW	275	Clear	☈5AM
30	29.92	67	72	58	.3390	.51	T		.70	NW	230	P.Cl.	
31	29.81	65	72	52	.2480	.42	.00		1.00	NW	276	Clear	
	29.96	62°	69°	52^{7}	.3347	.60	5.35	.00	.55	SE	6790		

JUNE 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow In Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.71	66°	74°	55°	.2670	.43	.00		.95	NW	258	Clear	
2	29.70	61	70	54	.2730	.57	T		.47	NE	147	P.Cl.	
3	30.00	52	62	48	.2920	.75	.05		.14	SE	199	Cloudy	☈11:20AM
4	29.89	61	67	53	.4290	.80	1.14		.00	SE	187	Cloudy	☈ dn
5	29.85	65	71	58	.3750	.63	.35		.50	N	177	P.Cl.	☈ dn
6	29.92	66	71	57	.3800	.60	T		.40	NW	143	P.Cl.	
7	30.11	62	68	52	.2990	.54	.00		.60	E	149	P.Cl.	
8	29.93	66	73	61	.3930	.62	.22		.50	SE	270	P.Cl.	
9	29.76	67	72	60	.5140	.76	1.21		.27	SE	170	Cloudy	☈2PM ▲
10	29.79	65	71	59	.4400	.72	.50		.27	NE	171	Cloudy	
11	29.96	69	77	55	.2700	.40	.00		1.00	N	157	Clear	
12	30.00	73	80	57	.3010	.39	.00		1.00	SE	70	Clear	
13	30.11	72	82	61	.3650	.48	T		.70	N	139	Clear	☈ 2:50PM
14	30.12	71	84	60	.4130	.57	.28		.90	NW	165	Clear	☈ 6:45PM
15	30.03	78	86	63	.4660	.48	.00		.90	NW	122	Clear	
16	30.00	80	88	66	.4910	.50	.00		.95	S	100	Clear	
17	29.93	81	89	69	.5190	.51	.00		1.00	SW	151	Clear	
18	29.92	82	91	70	.5940	.55	.00		.90	W	155	Clear	
19	29.89	79	91	68	.6090	.62	.16		.60	W	122	P.Cl.	☈ 3PM
20	29.86	82	91	66	.5640	.53	.00		1.00	NW	167	Clear	
21	29.83	81	91	68	.5970	.56	.00		1.00	NE	123	Clear	
22	29.87	82	89	71	.6480	.60	T		.66	SE	116	P.Cl.	
23	29.89	85	90	73	.6180	.53	.00		.80	S	88	Clear	
24	29.94	82	91	73	.6470	.61	T		.60	NW	100	P.Cl.	☈ 1:35PM
25	29.93	84	92	72	.6610	.57	.00		.75	SE	105	Clear	
26	29.92	81	93	75	.6880	.66	T		.60	W	112	P.Cl.	☈ 4:10PM
27	29.87	76	82	69	.7320	.83	1.28		.20	E	133	Cloudy	☈ dn
28	29.85	80	87	69	.5560	.58	.01		.70	NE	103	Clear	
29	29.92	82	90	68	.5890	.55	.00		.80	E	91	Clear	
30	29.91	80	87	70	.6540	.65	.00		.50	NE	84	P.Cl.	
	29.91	73^{7}	78^{8}	63^{3}	.4881	.59	5.20	00	.66	E	4274		

JULY 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.84	81°	87°	73°	.7160	.73	.00		.60	SE	111	P.Cl.	
2	29.78	76	83	67	.6990	.79	.50		.30	E	116	Cloudy	☈8:50AM
3	29.72	75	83	70	.6850	.79	1.68		.20	E	101	Cloudy	☈9:30AM
4	29.80	72	78	65	.5990	.74	.02		.60	N	189	P.Cl.	
5	29.83	78	84	69	.6320	.76	.58		.30	E	97	Cloudy	
6	29.84	79	89	71	.7410	.75	.09		.66	N	139	P.Cl.	☈4:40PM
7	29.78	83	90	70	.5670	.51	.00		.90	NW	120	Clear	
8	29.78	85	93	72	.6160	.53	.00		.95	W	123	Clear	
9	29.85	77	87	72	.7170	.77	.07		.60	S	184	P.Cl.	☈12.Noon
10	29.96	72	81	67	.6310	.82	.27		.20	NW	126	Cloudy	☈5.AM
11	29.95	76	83	69	.7010	.77	T		.60	S	137	P.Cl.	
12	29.90	77	82	70	.6840	.75	.02		.57	W	182	P.Cl.	
13	30.03	77	85	67	.6100	.68	.00		.60	N	114	P.Cl.	
14	29.94	81	90	71	.7080	.68	.00		.57	S	167	P.Cl.	☈3.PM
15	29.83	74	81	72	.7180	.85	.51		.28	S	185	Cloudy	☈4:15PM
16	29.71	79	86	69	.7330	.75	.03		.65	NW	202	P.Cl.	
17	29.77	81	88	75	.7670	.73	.00		.76	N	171	Clear	
18	30.02	73	79	61	.4280	.54	.00		1.00	NE	182	Clear	
19	30.14	73	82	60	.3080	.50	.00		1.00	E	110	Clear	
20	30.09	75	82	62	.4600	.55	.00		1.00	E	75	Clear	
21	29.92	79	86	65	.5240	.54	.00		.86	SW	113	Clear	
22	29.86	80	87	70	.6160	.62	.00		.75	S	170	Clear	
23	29.83	82	89	73	.6860	.64	.00		.70	S	232	P.Cl.	
24	29.85	84	91	76	.8290	.70	.07		.50	W	224	P.Cl.	
25	29.89	88	96	77	.8380	.64	.T		.75	W	169	P.Cl.	☈Hurricane
26	29.89	73	91	65	.6690	.83	1.10		.20	SE	180	Cloudy	
27	29.77	87	94	72	.8400	.66	.00		1.00	W	212	Clear	
28	29.80	85	93	76	.7700	.63	.00		.76	S	156	Clear	
29	29.78	79	89	72	.7660	.79	1.07		.57	N	189	P.Cl.	☈
30	29.89	79	85	75	.5190	.53	.00		1.00	N	171	Clear	
31	29.95	80	88	67	.4880	.59	.00		.72	N	85	Clear	
	29.90	79	86°	70	.6634	.66	6.01	.00	.65	S	4732		

AUGUST 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.92	80°	88°	68°	.5620	.54	.00		1.00	SE	123	Clear	
2	29.89	78	82	69	.6460	.69	.00		.50	SE	163	Cloudy	
3	29.82	76	85	69	.7180	.80	.31		.28	S	121	Cloudy	⛈
4	29.91	77	84	71	.4890	.64	.00		.85	NW	206	Clear	⌓²
5	29.91	74	81	61	.4330	.54	.00		.80	NW	117	Clear	
6	29.93	75	82	65	.5180	.61	.02		.43	N	69	P.Cl.	
7	29.92	67	73	65	.5490	.84	.88		.07	NE	122	Cloudy	
8	29.93	71	81	59	.5560	.77	.00		.64	S	143	P.Cl.	≡²
9	29.88	74	81	68	.6040	.73	.01		.50	W	181	P.Cl.	Rainbow
10	30.01	73	81	62	.4610	.58	.00		1.00	NW	133	Clear	⌓¹
11	30.05	73	79	63	.4710	.60	.00		.21	N	65	Cloudy	≡¹
12	30.02	77	84	65	.4990	.55	.00		.71	SE	132	Clear	
13	29.95	78	86	68	.4940	.53	.00		.66	SE	115	P.Cl.	
14	29.90	80	89	70	.5970	.59	.00		.60	SE	112	P.Cl.	
15	29.87	81	88	73	.6920	.68	.05		.60	S	168	P.Cl.	⛈1:50PM
16	29.86	82	92	73	.7410	.68	.00		.67	S	101	P.Cl.	
17	29.93	84	90	75	.7670	.68	.00		.67	S	105	P.Cl.	
18	30.04	76	84	73	.7160	.80	.51		.22	N	129	Cloudy	⛈11:15PM
19	30.07	76	83	66	.6160	.69	.00		.74	NE	116	Clear	⌓²
20	29.91	81	87	70	.6310	.60	.00		.81	S	106	Clear	≡¹
21	29.82	79	90	76	.7010	.72	.14		.59	S	145	P.Cl.	⛈4:40PM
22	29.98	84	93	70	.7920	.68	.00		.74	S	220	Clear	≡⁰
23	29.76	79	86	73	.7250	.74	.00		.67	S	351	P.Cl.	ϟ² dn
24	29.77	82	90	73	.7850	.75	.00		.60	S	281	P.Cl.	
25	29.95	73	84	66	.5700	.69	T		.37	N	274	Cloudy	ϟ dn
26	30.19	65	73	54	.2960	.50	.00		1.00	E	128	Clear	⌓²
27	30.06	68	75	54	.3360	.52	.00		1.00	SE	118	Clear	≡⁰
28	29.97	73	83	57	.4240	.55	.00		1.00	SE	109	Clear	≡²
29	29.95	79	87	65	.5750	.59	.00		1.00	SE	175	Clear	≡⁰
30	29.94	82	94	70	.6490	.60	.00		1.00	NW	153	Clear	
31	30.01	74	83	67	.6030	.73	.00		.65	N	200	P.Cl.	ϟ dn
	29.94	76°	84°	67	.5876	.65	1.92	.00	.66	S	4681		

SEPTEMBER 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.01	71°	80°	66°	.5750	.78	T		.69	NE	148	P.Cl.	
2	29.86	75	84	65	.6560	.77	.04		.54	W	114	P.Cl.	☈ 2:25PM
3	29.78	73	79	67	.6240	.78	T		.20	S	130	Cloudy	☈8:45PM
4	29.76	73	78	67	.7410	.91	3.64		.15	SE	217	Cloudy	☈7:30PM
5	29.77	77	86	71	.7540	.82	.12		.38	S	185	Cloudy	☈6:30AM and 4:20 PM
6	30.02	75	80	68	.5970	.71	.08		.70	W	132	P.Cl.	
7	30.06	73	80	71	.7580	.92	.57		.38	SE	144	Cloudy	☈10:30PM to 2:15 PM
8	30.02	81	89	73	.7260	.70	.00		.60	NW	194	P.Cl.	ϟ
9	30.16	64	81	59	.3840	.65	.00		1.00	N	241	Clear	
10	30.06	64	71	53	.3510	.59	.00		1.00	SE	132	Clear	$\equiv^0$
11	29.94	74	85	61	.5420	.64	.00		1.00	SE	229	Clear	$\equiv^0$
12	30.04	79	90	72	.7170	.74	.00		.80	S	180	Clear	ϟ
13	30.17	68	78	62	.5490	.82	.00		.40	N	177	P.Cl.	$\equiv^2$
14	30.27	66	73	60	.3720	.59	.00		.90	NE	180	Clear	
15	30.25	63	70	55	.3270	.57	T		.24	NE	87	Cloudy	
16	30.16	69	76	57	.3200	.48	T		.56	SE	148	P.Cl.	$\equiv^0$
17	30.07	73	83	59	.4060	.53	.00		1.00	S	139	Clear	
18	30.00	77	88	63	.5530	.62	.00		.80	SW	126	Clear	
19	29.89	77	86	69	.6040	.65	.02		.50	NW	174	P.Cl.	
20	29.91	74	85	65	.6080	.75	.00		.80	NE	96	Clear	$\equiv^2$
21	29.97	74	83	63	.4020	.54	.00		1.00	NE	103	Clear	$\equiv^1$
22	29.93	75	84	64	.4360	.52	.00		1.00	SE	150	Clear	$\equiv^0$
23	29.92	72	77	66	.6690	.86	.39		.00	SE	136	Cloudy	
24	29.93	67	76	65	.5090	.79	.42		.25	NW	163	Cloudy	☈dn
25	29.95	66	73	58	.4890	.77	T		.30	SE	114	Cloudy	⌓^{2}
26	29.88	69	76	64	.3650	.80	.33		.25	W	161	Cloudy	☈2A▲A° $\equiv^0$
27	30.12	59	70	53	.3040	.62	.00		.80	N	169	Clear	
28	30.16	62	71	49	.3240	.60	.00		1.00	N	65	Clear	⌓^{2}
29	30.05	66	75	53	.3650	.63	.00		.85	SE	76	Clear	$\equiv^2$
30	29.93	73	85	58	.5440	.67	.00		.90	S	172	Clear	⌓^{2}
	30.00	71	79^7	62^5	.5264	.69	5.61	00	.63	SE	4482		

OCTOBER 1910													
Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.93	76°	86°	69°	.5360	.61	.00	.00	.70	W	136	Clear	⌓²
2	29.91	75	87	62	.4780	.55	.00	.00	.60	SE	215	P.Cl.	
3	29.83	72	82	64	.5520	.71	.22	.00	.45	SE	272	Cloudy	‘
4	29.86	71	78	63	.6030	.81	.50	.00	.50	SE	255	P.Cl.	
5	29.83	69	72	67	.6550	.94	1.80	.00	.00	SE	182	Cloudy	•
6	30.15	56	67	50	.2810	.62	.43	.00	.70	N	269	Clear	•
7	30.31	57	64	46	.2350	.52	.00	.00	1.00	NE	81	Clear	⊓°
8	30.20	59	69	47	.2840	.59	.00	.00	1.00	N	91	Clear	⊓° ≡°
9	30.16	63	73	50	.2610	.49	.00	.00	1.00	N	129	Clear	
10	30.14	60	68	47	.3350	.67	.00	.00	1.00	E	70	Clear	≡²
11	30.04	63	74	52	.3580	.67	.00	.00	1.00	SE	73	Clear	≡²
12	30.01	68	77	54	.3870	.61	.00	.00	1.00	SE	91	Clear	≡²
13	29.96	69	80	58	.4440	.65	.00	.00	1.00	SE	96	Clear	≡²
14	30.05	69	79	60	.5520	.78	.00	.00	1.00	SE	78	Clear	≡²
15	30.06	73	84	62	.5420	.69	.00	.00	1.00	NW	93	Clear	≡²
16	29.98	73	83	62	.5050	.65	.00	.00	1.00	W	94	Clear	≡²
17	29.90	73	84	62	.4820	.62	.00	.00	1.00	SW	107	Clear	≡²
18	29.82	73	83	62	.4880	.62	.00	.00	1.00	SE	184	Clear	≡²
19	29.75	66	80	57	.4410	.70	.00	.00	.50	S	253	P.Cl.	≡°
20	29.98	46	57	45	.2500	.80	.04	.00	.00	N	198	Cloudy	
21	29.91	44	46	42	.2320	.81	.15	.00	.05	W	204	Cloudy	
22	29.96	50	60	38	.1870	.55	.00	.00	1.00	NW	176	Clear	⊓°≡²
23	30.02	56	70	41	.2320	.53	.00	.00	1.00	S	124	Clear	≡²
24	29.84	60	69	51	.2900	.57	.00	.00	1.00	W	201	Clear	
25	29.89	58	65	50	.1740	.40	.00	.00	1.00	NW	221	Clear	
26	29.61	68	83	51	.2740	.42	.00	.00	1.00	S	251	Clear	
27	30.02	45	72	42	.1650	.52	.05	.00	.80	NW	393	Clear	
28	30.25	34	43	31	.1210	.62	.00	T	.20	NW	371	Cloudy	
29	30.39	37	46	27	.1080	.54	.00	.00	1.00	W	166	Clear	Killing frost
30	30.14	54	68	38	.1390	.36	.00	.00	1.00	S	254	Clear	
31	30.13	58	69	47	.2070	.43	.00	.00	1.00	S	204	Clear	
	30.00	61	71°	51°	.3483	.61	3.19	T	.79	SE	5532		

NOVEMBER 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Peevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.93	57°	70°	44°	.2610	.55	.00	.00	.30	S	299	Cloudy	
2	30.26	39	47	33	.1067	.47	.00	.00	.95	NW	237	P.Cl.	
3	30.28	36	44	28	.0990	.49	.00	.00	1.00	N	129	Clear	$\equiv^{2}$
4	30.11	38	40	35	.1450	.63	T	.00	.00	SE	267	Cloudy	
5	30.17	41	46	37	.1330	.55	T	.00	.50	NW	259	P.Cl.	
6	30.06	44	56	29	.1200	.47	.00	.00	1.00	W	136	Clear	
7	29.81	55	68	38	.1860	.46	.00	.00	1.00	W	167	Clear	
8	29.87	51	60	41	.1980	.55	.00	.00	.80	SE	209	Clear	
9	29.69	64	74	52	.3320	.56	.00	.00	.70	S	251	P.Cl.	
10	30.02	41	68	38	.1470	.59	.00	.00	.80	NW	306	Clear	
11	30.10	36	42	32	.0955	.47	.00	.00	1.00	NW	214	Clear	
12	30.17	36	41	29	.1170	.57	.00	.00	.00	SE	119	Smoky	
13	29.85	42	48	35	.1260	.49	.00	.00	.00	SE	220	Cloudy	
14	29.94	40	45	38	.1390	.56	.00	.00	.80	NW	324	P.Cl.	
15	30.20	34	39	33	.1280	.68	.00	.00	.00	N	188	Cloudy	
16	30.23	33	40	28	.1150	.65	.00	.00	.00	NW	127	Cloudy	
17	30.13	33	40	26	.1370	.72	.00	.00	.80	NW	65	Clear	$\equiv^{2}\sqcap^{2}$
18	30.07	42	50	28	.1290	.50	.00	.00	.50	W	100	P.Cl.	$\sqcap^{2}$
19	30.15	36	47	27	.1390	.68	.00	.00	.80	NE	105	Clear	$\sqcap^{2}$
20	30.04	43	54	31	.2000	.76	.01	.00	.70	SE	191	P.Cl.	$\equiv^{0}\sqcap^{1}$
21	29.98	43	51	36	.2060	.74	.00	.00	.95	W	131	Clear	
22	30.00	42	52	29	.1680	.65	.00	.00	1.00	SE	214	Clear	$\equiv^{2}\sqcap^{2}$
23	29.85	54	59	47	.1690	.43	.00	.00	1.00	NW	227	Clear	
24	29.79	56	65	44	.1810	.39	.00	.00	1.00	NW	261	Clear	
25	30.02	48	56	38	.1600	.48	.00	.00	.50	NW	149	P.Cl.	
26	29.84	49	53	43	.2670	.72	.02	.00	.05	SE	315	Cloudy	●
27	29.68	50	65	39	.3300	.86	.16	.00	.05	NW	293	Cloudy	● $\equiv^{0}$ ☈
28	30.00	32	39	25	.1233	.76	.00	.00	.95	NW	325	Clear	
29	30.09	30	34	25	.1140	.68	.00	.00	.70	NW	220	P.Cl.	
30	30.20	26	31	22	.0748	.56	.00	.00	1.00	NW	447	Clear	
	30.02	42°	50°	34°	.1617	.59	.19	.00	.63	NW	6291		

DECEMBER 1910

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.24	22°	29°	16°	.0616	.55	.00	T	.10	NW	336	Cloudy	
2	30.26	26	32	16	.0790	.59	.00	.00	1.00	NW	169	Clear	
3	29.98	37	43	28	.1064	.53	.00	.00	.00	SE	204	Cloudy	
4	29.97	27	40	23	.1118	.76	.00	T	.00	NE	143	Cloudy	
5	29.88	30	32	27	.1450	.85	.00	.21	.00	N	277	Cloudy	
6	30.13	26	30	25	.0915	.71	.00	.00	.10	NW	235	Cloudy	
7	30.09	30	37	19	.1122	.67	.00	.00	1.00	W	158	Clear	
8	30.24	30	35	24	.0965	.59	.00	.00	.00	NE	66	Cloudy	
9	30.13	34	42	24	.1165	.60	.00	.00	.20	SE	150	Cloudy	
10	30.11	38	45	32	.1430	.63	.02	.00	1.00	NW	259	Clear	
11	30.34	32	40	28	.1170	.67	.00	.00	.40	NW	197	Cloudy	⌓
12	30.60	21	33	16	.0477	.53	.00	.00	1.00	N	177	Clear	⌓
13	30.70	27	34	16	.0867	.61	.00	.00	.50	SE	95	P.Cl.	⊓° ⌓
14	30.35	36	48	22	.0877	.46	.00	.00	1.00	S	159	Clear	⊓° ⌓
15	30.19	38	42	35	.1400	.61	.00	.00	1.00	NE	267	Clear	⌓
16	30.23	36	43	28	.1120	.55	.00	.00	1.00	SE	210	Clear	
17	30.11	44	53	32	.1600	.53	.00	.00	1.00	S	235	Clear	
18	29.98	37	46	26	.1390	.66	.00	.00	1.00	W	266	Clear	
19	29.76	39	46	31	.1240	.53	.00	.00	.90	NW	323	Clear	⌓
20	30.01	27	38	23	.0716	.50	.00	T	1.00	NW	351	Clear	
21	30.16	28	36	19	.0744	.48	.00	.00	1.00	SE	190	Clear	
22	29.99	35	36	31	.1590	.78	.03	T	.00	S	313	Cloudy	
23	30.00	31	38	27	.0930	.56	.00	.00	1.00	NW	330	Clear	
24	30.18	20	29	11	.0502	.48	.00	.00	1.00	NW	190	Clear	
25	30.05	35	41	22	.0981	.50	.00	.00	.00	SE	303	Cloudy	
26	30.10	36	45	29	.1250	.63	.00	.00	.85	NW	175	Clear	
27	29.97	39	45	31	.1900	.78	.26	.00	.05	SE	207	Cloudy	
28	29.85	41	52	38	.2010	.82	.27	.00	.00	NW	207	Cloudy	
29	29.94	34	40	27	.1750	.88	.30	.10	.00	NW	245	Cloudy	≡¹
30	30.39	28	35	20	.1123	.71	.00	.00	1.00	NW	186	Clear	
31	30.14	36	44	28	.1323	.77	.00	.00	1.00	S	381	Clear	⊓°
	30.13	33	40	25	.1186	.63	.88	.31	.62	NW	7005		

MONTHLY AND ANNUAL METEOROLOGICAL SUMMARY 1910.

	Atmospheric Pressure			Temperature					Moisture		Precipitation		Wind		Weather				Miscellaneous Phenomena								
	Mean	Highest	Lowest	Maximum	Minimum	Mean Maximum	Mean Minimum	Monthly Mean	Mean Vapor Pressure	Mean Relative Humidity	Rain	Melted Snow	Prevailing Direction	Total Mileage	Average Daily Sunshine	Number of Clear Days	Number of Cloudy Days	Partly Cloudy Days	Solar Halos	Lunar Halos	Thunderstorms	Hail	Sleet	Fog	Frost	Killing Frost	Date of Killing Frost
JANUARY	30.14	30.71	29.43	61	3	40.2	25.8	32.0	.1399	.75	2.81	0.14	NW	7115	.51	12	13	6	1	2	0	0	2	2	1		
FEBRUARY	30.17	30.70	29.56	64	-2	39.5	21.5	29.0	.1213	.69	1.40	2.01	SE	6606	.60	14	11	3	1	1	0	0	1	6	5		
MARCH	30.04	30.35	29.82	89	27	69.0	46.0	58.4	.2264	.47	0.14	0.00	SE	6168	.87	22	2	7	0	1	1	0	0	4	1		
APRIL	29.87	30.26	29.56	91	25	65.3	46.6	56.5	.2779	.60	4.27	0.35	SE	6864	.50	11	15	4	1	0	5	2	1	0	3	APR	23
MAY	29.96	30.40	29.63	86	40	69.6	52.7	62.6	.3347	.60	5.35	0.00	SE	6790	.55	11	12	8	0	3	7	1	0	3	0		
JUNE	29.91	30.17	29.64	93	48	78.3	63.3	73.7	.4881	.59	5.20	0.00	E	4274	.66	15	5	10	0	0	10	1	0	0	0		
JULY	29.90	30.16	29.66	96	60	86.5	70.0	79.0	.6634	.68	6.01	0.00	S	4732	.65	12	6	13	0	0	10	0	0	1	0		
AUGUST	29.94	30.23	29.74	94	54	84.5	67.0	76.5	.5876	.65	1.92	0.00	S	4681	.66	13	6	12	0	0	5	0	0	4	0		
SEPTEMBER	30.00	30.31	29.70	90	49	79.7	62.5	71.0	.5264	.69	5.61	0.00	SE	4482	.63	14	9	7	0	0	8	1	0	3	0		
OCTOBER	30.00	30.46	29.52	87	27	71.5	51.5	61.0	.3483	.61	3.19	T	SE	5532	.79	23	5	3	0	0	0	0	0	11	4	OCT	29
NOVEMBER	30.02	30.35	29.61	74	22	50.8	34.3	42.4	.1617	.59	0.19	0.00	NW	6291	.63	16	8	6	0	2	1	1	0	5	5		
DECEMBER	13.13	30.76	29.70	53	11	40.0	25.0	33.0	.1186	.63	0.88	0.31	NW	7005	.62	18	11	2	0	5	0	0	0	0	3		
ANNUAL	30.01	30.76	29.43	96	-2	64.6	47.2	54.0	.3380	.62	36.97	2.81	SE	70439	.64	181	103	81	3	14	47	6	4	39	22		

THE WEATHER OF 1911.

January, 1911.

With the exception of a very brief period at the opening of the month, the weather during January was mild for the season. The mean temperature, 36°, was 4° above normal. On 7 days the maximum was 60° or over, the highest being 73° on the 11th. At 8 P. M. January 1, the mercury stood at 48°, but within 12 hours fell to 4° above zero. On the 3rd the minimum was 2° below zero, but by the morning of the 5th a thaw had set in. The total precipitation was 1.22 in., including 0.17 in. of melted snow, whereas the normal for January is 2.39 in. A very unseasonable phenomenon was the thunderstorm accompanied by hail on the morning of the 27th.

February, 1911.

February's break with weather traditions was still more radical than that of the preceding month. The maximum temperature, 83°, registered on the 1st, is the highest for February on record in St. Louis. Almost unprecedented, likewise, was the fall of 50° in temperature within 12 hours, from 74° on the evening of the 1st to 24° on the morning of the 2nd. The normal mean temperature, 34°, was exceeded by 5°. Precipitation was slightly above the average. The snowfall, unmelted, amounted to 17 in.

March, 1911.

Heavy damage to property was caused by a violent storm on the morning of the 7th, and by the heavy gale of the 27th. The former was accompanied by lightning and hail. The gale, for a brief period, attained a velocity of 60-70 miles an hour. On March 28, the ground temperature at a depth of 5 ft., which since January 10 had remained constant at 46°, began to rise. The month closed with a snowfall of 4 inches.

April, 1911.

The total precipitation during April was 6.92 in., which was double the usual amount for this month. During the period of April 27th-30th, 4.15 in. fell. Several very heavy downpours occurred: 0.35 in. within 5 minutes on the 29th, and 0.65 in. within 15 minutes on the 30th. At 4:05 P. M. April 13th a very severe storm broke over the western and northern residence sections of the city, causing damage to the extent of over $1,000,000. While there was no tornadic formation, the wind attained high velocities and there was a very destructive fall of hail. At the observatory, which was on the eastern edge of the storm's path, the anemometer registered 58 miles per hour. Along the river front there was a heavy fall of rain, but no hail and only light winds. Within the storm area practically all windows facing the west were shattered. Many of the hailstones were larger than hen's eggs, some regular in shape, others composed of smaller stones frozen together. Florists and gardeners suffered heavily from the destruction of their greenhouses. Several storms of similar character occurred at various places just west of the Mississippi on the 12th and 13th. Temperature was about normal, and there was no frost during this month.

May, 1911.

The total precipitation was 1.85 in. Records show that smaller amounts fell during May in only two other years, 1879 and 1897. This amount was distributed over only six days, almost half of it falling during the violent thunderstorm on the 28th. The temperature was unusually high for May, especially during the latter half of the month. A maximum of 94° was reached on the 25th, 26th, and 28th, and 93° on the 24th and 27th.

June, 1911.

The normal mean temperature, 75°, was exceeded by 6°. On the 9th the maximum reached 98°.5 and on the 10th 99°, the highest temperature in St. Louis for the respective dates since 1836. The low relative humidity, however, generally 50% or less, made the extreme heat somewhat bearable. There were 15 clear days and an average daily sunshine of 76%.

July, 1911.

During the first two weeks the weather was unusually hot, even for July. The maximum temperature on the first 5 days was above 95°, and on the 3rd and 4th it reached 101°. The thermometer registered 90°, or over, on 17 days. The latter half of the month, however, was much cooler, 8 days having a mean temperature, which was 3 to 8 degrees below the seasonal average. The mean temperature for the month was only 2° above the normal. With the exception of 1890, this was the driest July since 1839, the total precipitation being only 0.74 in. Only two thunderstorms passed over the city. Twelve deaths and numerous prostrations were caused by the heat.

August, 1911.

The departure of the mean temperature from the normal by 1° was due to the very unseasonable cool weather which prevailed during the last third of the month. Prior to the 19th the heat, while not unusual, was rather oppressive, owing to the high percentage of humidity. Rain fell on 10 days, the total, 4.72 in., exceeding the average by 2.28 in.

September, 1911.

A mean temperature of 75°, 5° above the normal; rainfall amounting to 7.30 in.—the normal quantity being 3 in.; twelve thunderstorms, and an average relative humidity of 73%, characterize weather conditions during September. On the night of September 4th-5th, occurred the heaviest downpour of the year, 2.64 in.

October, 1911.

There were no striking features in weather conditions during this month. With only four perfect days, this month bears poor comparison with October, 1910, which had 20.

November, 1911.

The mean temperature during January, February, March, June and September was far above the normal, but that of November was not less than 5° below the average. Some very remarkable changes in temperature occurred on the night of November 11th-12th. On the afternoon of the 11th the maximum temperature had been 77°. When the cold wave, which had been advancing from the Northwest, reached St. Louis at 6:04 P. M., the thermometer still registered 76°. Then with the abrupt veering of the wind from southeast to northwest—the velocity suffering little diminution from 30 miles per hour—the temperature fell sharply. Within ten minutes it fell to 54°, and by 11 o'clock P. M. had reached 20°. The minimum recorded at 7 A. M. of the 12th was 13°. The total range within 12 hours was 63°; 22° within the first 10 minutes, and 56° within the first 5 hours.

December, 1911.

Fog, which prevailed on 10 days, was an unpleasant feature of the month's weather. On the 13th the average humidity was 100%. The mean temperature was below freezing on only four days. The minimum, 11°, occurred on the last day of the month, ushering in a period of the coldest weather for years.

JANUARY 1911.

Date	Mean Atmospheric Pressure	Mean Temperature °F°	Maximum Temperature °F°	Minimum Temperature °F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.79	44°	48°	37°	.2570	.91	.14	.00	.00	SE	258	Cloudy	
2	30.34	7	48	4	.0278	.51	.03	.10	.95	W	432	Clear	C.W.
3	30.45	3	7	-2	.0245	.57	.00	T	1.00	NW	307	Clear	
4	30.29	20	32	3	.0547	.55	.00	.00	.75	W	281	Clear	
5	30.06	34	44	20	.0887	.46	.00	T	.20	SE	248	Cloudy	
6	30.12	37	46	24	.1210	.57	.00	.00	.75	S	147	Clear	
7	29.87	44	54	37	.1340	.45	.00	.00	.90	S	172	Clear	◡
8	29.86	42	48	35	.1264	.47	.00	.00	.95	NW	392	P.Cl.	
9	30.36	32	39	23	.0954	.56	.00	.00	.80	SE	245	P.Cl.	,
10	29.90	49	60	32	.2223	.58	.00	.00	.95	S	368	P.Cl.	⌓
11	29.88	57	73	36	.3620	.74	.00	.00	.18	S	269	Cloudy	⌓²
12	30.22	31	36	24	.1480	.86	T	.00	.00	NW	137	Cloudy	
13	30.18	35	40	31	.1930	.94	.43	.00	.00	N	127	Cloudy	≡² Δ²
14	30.12	35	38	31	.1820	.89	T	.00	.00	N	150	Cloudy	≡°
15	30.35	21	32	18	.0798	.73	.00	.00	.80	N	261	P.Cl.	
16	30.40	26	29	19	.0823	.60	T	.00	.00	E	168	Cloudy	Δ°
17	30.26	28	29	27	.1280	.86	.05	T	.00	N	156	Cloudy	Δ²
18	30.35	26	30	22	.1150	.82	.00	.00	.00	W	86	Cloudy	Δ°
19	30.19	38	45	28	.1830	.80	.00	.00	.90	W	159	P.Cl.	
20	29.78	45	51	33	.2260	.75	.00	.00	.15	S	193	Cloudy	
21	29.99	30	50	26	.1046	.63	.01	.05	.00	N	282	Cloudy	
22	30.33	25	28	21	.0982	.66	.00	.02	.10	N	164	Cloudy	C.W.
23	30.57	33	41	22	.1030	.57	.00	.00	.90	S	153	Clear	⊓°
24	30.41	41	46	32	.1210	.48	.00	.00	.30	SE	189	Cloudy	
25	30.19	47	49	42	.2640	.81	.00	.00	.00	SE	230	Cloudy	
26	29.94	62	68	48	.4220	.76	.00	.00	.30	S	275	Cloudy	
27	30.07	51	63	40	.3440	.88	.39	.00	.10	NW	257	Cloudy	▲° Ꚍ
28	30.37	42	47	36	.1880	.70	.00	.00	.30	SE	220	Cloudy	
29	29.79	59	67	46	.3800	.77	.00	.00	.20	S	309	Cloudy	
30	30.14	32	60	26	.1204	.67	.00	.00	.90	NW	229	P.Cl.	
31	29.76	50	62	34	.2060	.56	.00	.00	.75	SE	212	Cloudy	
	30.14	36^{3}	45^{6}	27^{6}	.1672	.68	1.05	.17	.45	S	7045		

FEBRUARY 1911.													
Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.63	62°	83°	44°	.2800	.54	.00	.00	1.00	SE	339	Clear	
2	30.21	31	74	24	.1050	.60	.00	.00	1.00	NW	286	Clear	C.W.
3	29.70	36	44	28	.1600	.73	T	.00	.05	SE	216	Cloudy	
4	30.11	35	41	27	.1060	.56	.00	.00	1.00	NW	199	Clear	◓
5	29.97	34	39	32	.1460	.75	.33	.09	.00	SE	312	Cloudy	Δ^2
6	29.94	33	41	30	.1390	.75	.09	.00	.00	W	290	Cloudy	
7	30.03	31	37	27	.1410	.87	T	.00	.00	SE	216	Cloudy	◓
8	30.22	33	41	26	.1300	.70	.00	.00	.80	N	185	Cloudy	⊕ ◒
9	30.21	34	40	29	.0872	.48	.00	.00	1.00	W	269	Clear	$\sqcap^2$
10	30.36	30	38	20	.0754	.47	.00	.00	.50	SE	195	Clear	⊕ ◒
11	30.19	39	45	34	.1660	.68	T	T	.15	SE	193	Cloudy	
12	30.08	40	43	39	.2030	.82	T	.00	.00	S	217	Cloudy	
13	29.80	50	57	39	.2960	.83	T	.00	.35	S	327	Cloudy	
14	29.71	53	58	48	.2700	.68	.25	.00	.50	W	292	P.Cl.	
15	30.04	55	69	38	.2630	.62	.00	.00	1.00	SE	212	Clear	
16	30.06	65	75	55	.5430	.79	.46	.00	.40	SE	216	P.Cl.	T↘
17	30.10	64	77	52	.4000	.70	.00	.00	1.00	S	263	P.Cl.	
18	30.23	37	52	35	.2050	.92	.67	.00	.00	N	225	Cloudy	Δ^1
19	30.06	29	36	27	.1430	.90	.13	1.20	.00	N	279	Cloudy	
20	30.29	22	28	21	.0799	.70	.00	.09	.65	W	301	Cloudy	
21	30.63	19	25	15	.0552	.57	.00	.00	.90	NW	261	Clear	
22	30.51	24	30	16	.0771	.61	.00	.00	1.00	W	305	Clear	
23	30.44	29	38	19	.1240	.78	.00	.00	1.00	W	147	Clear	$\equiv^{\circ}$
24	30.23	35	45	24	.0892	.47	.00	.00	1.00	W	219	Clear	
25	29.87	44	51	34	.1347	.47	T	.00	.65	SE	227	Cloudy	
26	30.03	44	49	40	.1910	.68	T	.00	.80	W	266	Clear	
27	30.56	34	41	28	.1220	.65	.00	.00	.95	N	209	Clear	
28	30.56	29	37	24	.0997	.66	.00	.28	.37	N	187	Cloudy	
	30.13	39	47^6	31^3	.1725	.67	1.93	1.66	.56	W	6859		

MARCH 1911.

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.11	28°	34°	24°	.1203	.78	.00	.02	.87	W	199	Clear	
2	30.01	37	46	26	.1137	.54	.00	.00	1.00	W	240	Clear	⊓^{1}
3	29.92	49	59	37	.1770	.53	.00	.00	1.00	W	152	Clear	
4	30.32	41	55	32	.1330	.56	.00	.00	.95	N	171	Clear	
5	30.02	49	62	33	.2310	.63	.09	.00	.43	SE	316	P.Cl.	
6	30.18	47	64	44	.2340	.75	T	.00	.60	E	169	P.Cl.	
7	30.08	44	48	40	.2440	.84	.72	.00	.00	N	194	Cloudy	☈ ▲^{1}Hurricane
8	30.13	47	57	37	.2190	.71	.02	.00	.70	SE	197	P.Cl.	⊕
9	29.79	61	76	43	.3410	.64	.00	.00	.77	SE	244	Clear	
10	30.04	55	62	47	.3080	.50	.00	.00	.57	N	172	P.Cl.	⊕
11	29.61	64	80	48	.3120	.53	.00	.00	.51	SE	279	P.Cl.	
12	30.03	47	76	36	.2510	.85	.01	.00	.09	N	318	Cloudy	☈
13	30.38	41	50	30	.1460	.58	.00	.00	.90	N	238	Clear	
14	30.14	46	56	32	.1200	.42	.00	.00	1.00	W	140	Clear	≡° ⊓
15	30.34	30	53	25	.0735	.44	.00	.00	1.00	NW	436	Clear	Gale
16	30.33	30	38	21	.0691	.41	.00	.00	.50	SE	201	Clear	
17	29.87	51	66	33	.2270	.60	.28	.00	.25	SE	282	Cloudy	
18	30.17	39	53	30	.1370	.59	.03	.00	1.00	E	166	Clear	
19	29.96	50	59	38	.1330	.42	.00	.00	1.00	W	265	Clear	
20	30.02	60	70	46	.1720	.33	.00	.00	1.00	W	190	Clear	
21	29.86	66	77	52	.1426	.37	.00	.00	.85	SE	218	P.Cl.	
22	30.00	56	69	52	.2500	.52	.04	.00	.80	N	336	P.Cl.	
23	30.41	45	52	35	.1370	.44	.00	.00	1.00	N	115	Clear	
24	30.36	43	52	33	.0910	.35	.00	.00	.95	SE	315	Clear	
25	30.03	55	70	37	.2030	.45	.00	.00	.85	SE	267	Clear	
26	29.67	54	61	48	.3560	.86	.81	.00	.05	S	292	Cloudy	
27	29.94	42	60	32	.1370	.56	.00	T	1.00	W	606	Clear	Δ^{1} Hurricane
28	29.71	50	64	35	.1650	.45	T	.00	.35	SE	265	Cloudy	
29	29.54	45	57	36	.1870	.67	.01	.00	.45	W	441	P.Cl.	Gale
30	29.80	37	44	31	.1100	.50	.00	.00	.40	W	414	P.Cl.	
31	29.97	37	44	31	.1700	.80	.00	.40	.15	SE	99	Cloudy	
	30.01	46°	58°	36°	.1842	.57	2.01	.42	.68	SE	7937		

APRIL 1911.

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.12	43°	48°	33°	.1050	.41	.00		.40	NW	127	P.Cl.	
2	29.84	48	62	37	.1860	.55	T		.35	S	338	Cloudy	R ● ⌓
3	29.86	46	50	41	.2630	.85	.37		.00	N	174	Cloudy	ϟ $\equiv^2$
4	29.42	61	69	48	.3410	.71	.16		.05	E	183	Cloudy	R $\equiv^2$ ▲
5	29.74	47	55	42	.2380	.74	.00		.35	W	279	Cloudy	
6	29.65	49	74	42	.2890	.77	.00		.45	S	387	P.Cl.	⌓
7	30.13	40	46	33	.1100	.46	.00		.40	E	131	P.Cl.	
8	30.19	47	54	40	.1670	.54	.00		.80	N	173	P.Cl.	
9	30.42	47	54	38	.1820	.59	.00		.85	E	159	Clear	
10	30.26	51	59	40	.1770	.48	.00		.85	SE	311	Clear	◒ ⌓
11	29.96	51	56	48	.2970	.83	.18		.00	SE	303	Cloudy	
12	29.81	64	74	47	.3970	.71	.00		.75	SE	362	Clear	⌓ Double ring
13	29.84	59	70	50	.4610	.92	1.30		.25	SE	346	Cloudy	R ▲ Hurricane
14	30.29	49	52	44	.1650	.48	.77		.75	N	265	Clear	R
15	30.29	55	62	42	.1500	.37	.00		1.00	W	257	Clear	
16	30.07	60	69	44	.1510	.34	.00		1.00	W	139	Clear	
17	30.00	64	75	50	.1740	.32	.00		.85	W	199	P.Cl.	⊕
18	29.85	57	68	53	.4030	.84	.30		.00	S	234	Cloudy	
19	29.71	58	63	52	.2900	.63	.05		.62	W	369	Cloudy	ϟ
20	30.00	61	67	52	.3100	.60	.00		.58	N	159	Cloudy	
21	29.93	63	70	52	.2670	.51	.00		.86	W	196	Clear	
22	30.10	52	66	44	.1720	.45	.00		1.00	N	168	Clear	
23	30.30	52	59	41	.1610	.44	.00		1.00	NE	120	Clear	
24	30.28	53	60	41	.2250	.48	.00		.75	NE	109	Clear	$\equiv^1$
25	30.22	56	63	43	.2090	.48	.00		1.00	SE	159	Clear	⊕
26	30.09	63	73	52	.2600	.44	.00		.75	SE	218	Cloudy	
27	30.08	55	66	51	.3890	.89	.57		.00	SE	333	Cloudy	
28	30.00	62	73	56	.4660	.83	.00		.00	SE	221	Cloudy	
29	29.84	65	68	59	.5190	.85	1.53		.05	SE	223	Cloudy	R ▲
30	29.57	65	69	58	.4640	.81	1.80		.12	S	265	Cloudy	R
	30.00	55	63^2	45^6	.2663	.61	6.92	.00	.53	SE	7035		

MAY 1911.

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.81	44°	64°	41°	.2170	.74	.06	T	.01	W	402	Cloudy	Gale
2	30.15	50	58	37	.1710	.47	.00		1.00	W	171	Clear	
3	30.21	49	54	44	.2140	.63	T		.03	W	108	Cloudy	$\equiv^1$
4	30.25	57	65	44	.2150	.50	.00		1.00	N	108	Clear	
5	30.31	59	66	46	.1850	.39	.00		1.00	E	92	Clear	$\equiv^1$
6	30.26	63	69	49	.2450	.44	.00		1.00	SE	171	Clear	$\equiv^1$
7	30.23	67	77	54	.2670	.41	.00		1.00	SE	177	Clear	
8	30.01	73	83	56	.3510	.44	.00		1.00	S	174	Clear	
9	29.79	79	89	67	.4250	.44	.00		.81	W	209	Clear	
10	29.66	77	86	66	.4540	.50	.00		1.00	S	283	Clear	
11	29.85	70	78	64	.3550	.50	.00		.85	W	181	P.Cl.	◓
12	30.04	72	80	59	.3450	.45	.00		.92	W	75	P.Cl.	●
13	30.10	75	84	63	.4100	.47	.00		.95	SE	244	P.Cl.	
14	30.08	75	84	64	.4120	.49	.00		.94	SE	290	Clear	
15	30.00	79	88	65	.4740	.47	.00		.85	SE	205	Clear	
16	29.95	80	88	69	.5010	.50	.00		.81	SE	175	P.Cl.	
17	29.92	82	90	71	.6060	.55	.00		.93	SE	166	P.Cl.	
18	29.75	82	91	72	.5750	.54	T		.74	SE	210	P.Cl.	
19	29.58	81	88	72	.6020	.58	.00		.87	SE	345	P.Cl.	
20	29.66	74	84	66	.5890	.71	.43		.54	S	213	P.Cl.	ꓘ
21	29.77	72	79	65	.5490	.71	.15		.52	S	262	P.Cl.	
22	29.86	73	81	60	.4420	.54	.00		.71	S	166	Clear	
23	29.99	71	78	58	.3510	.48	.01		1.00	W	160	Clear	
24	30.02	82	93	63	.4660	.44	.00		1.00	S	160	Clear	
25	29.97	84	94	70	.5060	.45	.00		1.00	S	151	Clear	
26	29.93	85	94	71	.4910	.45	.00		1.00	S	160	Clear	
27	29.94	86	93	72	.5680	.46	.00		.95	S	133	Clear	
28	30.00	81	94	66	.6690	.64	.90		.58	S	130	P.Cl.	ꓘ ▲
29	30.00	78	89	68	.5910	.65	.00		.86	N	107	Clear	ꓘ
30	29.98	79	87	68	.6950	.70	T		.51	N	99	P.Cl.	
31	29.90	78	84	65	.6160	.71	.30		.80	W	199	P.Cl.	
	29.97	72°	76°	61	.4373	.53	1.85	T	.81	S	5740		

JUNE 1911

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain In Inches	Melted snow In Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.97	73°	80°	62°	.4740	.57	.00		1.00	E	137	P.Cl.	
2	29.91	78	86	65	.5010	.53	.00		1.00	SE	251	P.Cl.	
3	29.91	89	98	74	.6770	.50	.00		.92	S	174	Clear	
4	29.91	89	98	77	.6550	.48	.00		1.00	W	169	Clear	
5	29.85	87	96	77	.6460	.52	.00		.80	W	185	Clear	●
6	29.93	76	88	66	.6390	.74	.28		.88	W	195	Cloudy	⛈2AM.
7	30.00	82	88	69	.6380	.60	.00		1.00	N	100	Clear	
8	29.98	81	90	67	.5380	.51	.00		.95	SE	149	Clear	
9	29.90	88	98	72	.6310	.49	.00		1.00	SE	174	Clear	
10	29.81	89	99	76	.5380	.40	.00		1.00	S	193	Clear	
11	29.79	81	92	73	.5960	.58	T		.85	W	230	Clear	
12	29.79	73	83	65	.4250	.54	.00		.48	W	293	P.Cl.	
13	29.84	76	84	62	.4790	.54	.00		1.00	NW	148	P.Cl.	
14	29.85	73	81	63	.5220	.65	.15		.55	W	116	P.Cl.	
15	29.84	79	88	65	.4420	.47	.00		.81	SE	210	P.Cl.	
16	29.69	86	98	70	.5550	.47	.00		.60	SE	174	P.Cl.	
17	29.61	86	94	80	.5790	.48	T		.42	W	184	Cloudy	
18	29.79	70	84	66	.6390	.80	.15		.14	NW	164	Cloudy	
19	29.90	78	86	68	.5500	.58	T		.92	NE	142	Clear	
20	29.97	84	92	67	.5030	.45	.00		.98	E	125	Clear	
21	29.97	88	96	72	.5630	.44	.00		.95	SE	124	Clear	
22	29.95	85	93	75	.6330	.54	.00		.82	SE	171	Clear	
23	29.87	77	82	73	.6670	.79	.20		.17	SE	180	Cloudy	ϟ
24	29.84	77	83	70	.7660	.83	.35		.45	S	186	Cloudy	⛈1PM.
25	29.79	82	87	73	.7350	.67	.05		.57	S	188	P.Cl.	⛈9:25AM
26	29.81	81	87	75	.8300	.78	.18		.50	S	251	Cloudy	⛈6:30AM
27	29.92	79	86	66	.5570	.59	.43		.80	W	179	Clear	⛈
28	29.95	81	87	66	.5850	.56	.00		.70	E	121	Clear	
29	29.99	84	92	71	.5780	.53	.00		.72	SE	175	Clear	
30	30.03	88	95	74	.6160	.48	.00		.95	SE	171	Clear	
	29.88	81°	90°	70°	.5919	.57	1.79	.00	.75	S	5273		

JULY 1911.

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.00	88°	96°	76°	.5860	.42	.00		.93	SE	205	Clear	
2	29.91	91	98	79	.6460	.44	.00		1.00	SE	121	Clear	
3	29.86	91	101	78	.6410	.47	.00		1.00	W	106	Clear	
4	29.88	92	101	80	.7250	.49	.00		1.00	S	125	Clear	◓
5	29.88	90	99	80	.7410	.54	.00		1.00	S	150	Clear	
6	29.97	86	94	76	.6720	.56	.00		.83	S	174	P.Cl.	◓
7	29.92	86	94	75	.6690	.56	.00		.89	SE	154	P.Cl.	
8	29.90	84	90	75	.6760	.60	.00		.75	SE	252	P.Cl.	
9	29.96	83	94	74	.6850	.63	.00		.85	S	213	P.Cl.	
10	29.97	84	92	77	.7750	.68	.00		.50	W	187	P.Cl.	
11	29.92	85	98	75	.7170	.60	T		.53	S	127	P.Cl.	⚡4:15PM
12	29.99	82	91	70	.5520	.53	.00		1.00	N	177	Clear	
13	30.09	81	90	68	.4270	.42	.00		1.00	N	145	Clear	
14	30.09	84	91	69	.4660	.42	.00		1.00	N	96	Clear	
15	29.98	85	94	73	.4490	.37	.00		.85	SE	159	P.Cl.	
16	29.92	76	88	67	.5000	.59	.18		.65	W	228	P.Cl.	
17	29.95	72	78	63	.3560	.45	.00		.36	W	119	Cloudy	Meteor
18	29.92	76	82	59	.4710	.52	.00		.67	S	167	P.Cl.	
19	29.91	71	80	68	.6190	.83	.18		.07	S	128	Cloudy	
20	29.89	74	79	69	.6860	.82	T		.37	SE	127	Cloudy	
21	29.83	83	91	70	.5930	.60	.00		1.00	N	99	Clear	⌓
22	29.88	82	90	68	.3880	.36	.00		1.00	E	95	Clear	
23	29.65	82	88	72	.6860	.64	.29		.50	SE	287	Cloudy	⚡9:45AM
24	30.00	69	87	61	.3390	.50	.00		.95	NW	398	Clear	
25	30.08	70	78	57	.3080	.45	.00		.81	W	272	Clear	
26	30.10	73	81	56	.3600	.46	.00		1.00	N	100	Clear	≡°
27	30.00	78	88	63	.4100	.43	.00		.64	SE	193	P.Cl.	
28	29.97	74	80	67	.5080	.62	T		.40	S	186	Cloudy	
29	29.95	78	84	69	.6990	.70	.09		.54	S	143	P.Cl.	ϟ
30	29.98	78	85	66	.6160	.67	.00		.70	SE	188	P.Cl.	⌓
31	29.84	79	86	70	.6310	.66	T		.33	S	234	Cloudy	
	29.94	80°	89	70	.5667	.55	.74	.00	.74	S	5356		

AUGUST 1911													
Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.77	76°	87°	70°	.6920	.77	.40		.34	W	156	Cloudy	ㄎ
2	29.90	79	86	69	.4650	.49	.00		.72	N	109	Clear	
3	29.86	77	86	68	.6620	.73	.45		.60	SE	202	P.Cl.	ㄎ
4	29.89	77	84	68	.6230	.71	.07		.42	W	85	P.Cl.	● ⌓²
5	29.87	79	84	68	.6460	.67	.00		.93	SE	110	Clear	●
6	29.85	82	90	71	.7080	.67	.00		.98	SE	125	Clear	≡²
7	29.84	80	88	66	.7120	.69	.48		.54	SE	235	P.Cl.	ㄎ
8	29.86	84	92	69	.8020	.70	1.26		1.00	N	130	Clear	ㄎ≡⁰
9	29.92	84	96	74	.7550	.67	.00		.81	SE	134	Clear	
10	29.96	85	94	73	.7960	.67	.00		.70	SE	207	Clear	
11	29.95	88	95	77	.8300	.64	.00		.63	SE	134	P.Cl.	
12	29.99	87	93	77	.7340	.59	.00		.80	SE	168	Clear	ϟ
13	30.00	80	89	74	.7080	.70	T		.68	SE	246	P.Cl.	
14	29.92	79	84	74	.7320	.73	.00		.16	SE	180	Cloudy	
15	29.88	84	91	73	.7240	.63	.00		.60	E	75	P.Cl.	
16	29.87	86	95	74	.6690	.55	.00		.66	SE	97	Clear	
17	29.86	83	93	75	.7000	.64	.00		.52	W	157	P.Cl.	Dry ㄎ
18	29.95	82	91	70	.6320	.59	.00		1.00	N	120	Clear	
19	30.00	71	85	65	.4680	.62	.06		.17	SE	157	Cloudy	ㄎ
20	29.93	76	85	65	.4170	.45	.00		1.00	E	120	Clear	
21	29.89	73	82	66	.4810	.60	.02		.23	S	182	Cloudy	
22	29.94	74	79	69	.6310	.73	.00		.22	S	137	Cloudy	
23	30.08	65	76	60	.4830	.82	.05		.00	N	191	Cloudy	
24	29.99	62	67	57	.4940	.89	1.33		.05	N	144	Cloudy	≡•
25	29.94	69	76	59	.5110	.74	.00		.45	N	97	P.Cl.	⌓² ≡⁰
26	29.94	70	76	62	.5430	.75	.00		.27	SE	128	Cloudy	⌓²
27	29.89	75	84	67	.6920	.80	.00		.30	SE	130	Cloudy	≡²
28	29.99	69	77	63	.4020	.57	.60		.77	N	244	Clear	
29	30.11	65	73	54	.3430	.57	.00		1.00	N	184	Clear	
30	30.02	66	77	52	.3400	.57	.00		1.00	N	112	Clear	⌓²
31	29.98	72	85	56	.4180	.57	.00		1.00	W	80	Clear	⌓²
	29.93	76'	85	67	.6062	.66	4.72	00	.60	SE	4556		

SEPTEMBER 1911

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.99	79°	90°	64°	.5360	.56	.00		1.00	S	131	Clear	
2	29.93	81	92	66	.6330	.62	.00		1.00	W	153	Clear	⌓¹
3	29.97	79	90	69	.6240	.62	.00		.95	N	136	Clear	
4	29.94	75	85	63	.6640	.74	T		.08	SE	149	Cloudy	☈4PM
5	29.81	76	82	67	.6760	.76	2.64		.54	W	139	P.Cl.	
6	29.83	80	90	68	.7170	.74	.00		.70	SE	140	Clear	≡¹ ⌓²
7	29.94	74	83	66	.6470	.78	.45		.46	N	200	P.Cl.	☈12:40AM
8	30.06	74	84	68	.6690	.81	.14		.10	N	99	Cloudy	●
9	30.09	76	83	66	.6610	.75	.00		.60	E	93	P.Cl.	≡² ⌓²
10	29.95	75	80	72	.7380	.85	.38		.05	W	158	Cloudy	≡¹ ●
11	29.85	78	86	67	.6550	.73	T		.63	W	101	P.Cl.	
12	29.36	81	90	73	.8060	.76	.00		.80	N	117	Clear	
13	29.95	76	85	60	.6690	.75	.05		.50	E	231	P.Cl.	☈9:30PM
14	29.86	35	95	71	.7660	.66	.00		.95	S	232	Clear	ϟ ⌓²
15	29.36	82	90	77	.7660	.72	.00		.60	W	206	P.Cl.	☈4:45PM
16	29.92	75	83	68	.7150	.82	.75		.05	W	112	Cloudy	☈7:30PM
17	29.84	78	85	70	.7940	.83	1.49		.60	SE	212	P.Cl.	☈4:30AM
18	29.88	78	88	72	.7630	.90	.03		.42	N	178	P.Cl.	☈12:45PM
19	30.06	66	74	60	.3730	.60	.00		.75	N	219	Clear	
20	29.93	68	74	57	.4420	.66	T		.58	SE	161	P.Cl.	
21	29.99	65	72	60	.4010	.70	.14		.40	NW	218	P.Cl.	
22	30.15	67	74	55	.4370	.70	.00		1.00	E	106	Clear	≡² ⌓²
23	30.06	70	80	58	.4660	.67	.00		1.00	SE	133	Clear	≡² ⌓²
24	29.98	78	88	66	.6580	.70	.00		.75	S	157	Clear	
25	30.02	72	80	67	.6770	.88	.25		.01	S	170	Cloudy	☈ ≡⁰
26	30.12	66	73	62	.5720	.89	.98		.03	E	135	Cloudy	☈ ≡²
27	29.95	80	90	66	.7330	.73	T		1.00	S	152	Clear	≡² ⌓²
28	29.88	80	90	71	.7530	.74	T		.51	SE	165	P.Cl.	☈
29	29.97	71	82	66	.4810	.64	T		.11	N	218	Cloudy	☈
30	29.99	66	74	58	.4520	.71	.00		.43	SE	174	P.Cl.	
	29.98	74⁷	83⁷	66	.6315	.73	7.30	00	.56	SE	4795		

OCTOBER 1911.

Date	Mean Atmospheric Pressure	Mean Temperature, F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	29.72	72°	75°	67°	.6930	.89	1.15		.01	S	186	Cloudy	π
2	29.76	65	74	62	.5490	.89	.06		.00	E	154	Cloudy	$\equiv^0$
3	29.77	78	89	63	.6330	.72	T		.70	S	253	P.Cl.	$\equiv^2$ ϟ
4	30.04	66	80	63	.3960	.63	.12		.65	W	220	P.Cl.	π
5	30.10	62	69	54	.3700	.66	T		.25	SE	247	Cloudy	⌓
6	29.69	75	88	61	.6450	.75	.07		.60	W	309	P.Cl.	π
7	30.02	52	74	49	.3370	.86	.01		.00	N	290	Cloudy	
8	30.18	52	55	49	.2500	.63	.00		.00	N	169	Cloudy	
9	30.11	57	62	52	.3260	.72	.00		.17	W	80	Cloudy	
10	30.08	61	67	54	.3460	.64	.00		.65	SE	80	Clear	$\equiv^0$
11	30.08	63	71	50	.4490	.79	.00		.13	SE	82	Cloudy	$\equiv^2$ ⊖
12	30.09	65	72	57	.3520	.58	.00		1.00	E	89	Clear	$\equiv^1$
13	30.02	62	68	57	.3830	.69	.00		.26	SE	130	Cloudy	
14	29.86	66	75	57	.4730	.74	T		.80	W	160	Clear	
15	29.80	70	82	57	.5260	.71	.04		.80	SE	225	Clear	
16	29.68	64	75	60	.4210	.70	T		.20	W	242	Cloudy	
17	29.76	60	66	53	.3100	.60	.00		.36	NW	195	P.Cl.	
18	29.87	60	70	47	.3040	.61	.00		1.00	SE	168	Clear	$\equiv^2$
19	29.97	56	65	51	.3230	.72	.00		.90	N	173	Clear	●
20	30.09	49	54	47	.2870	.83	.34		.00	N	126	Cloudy	
21	30.11	43	49	39	.2500	.90	.76		.00	N	222	Cloudy	
22	30.03	47	56	36	.1780	.59	.02		1.00	W	196	Clear	
23	30.16	47	55	40	.1740	.55	.00		1.00	W	207	Clear	$\sqcap^0$
24	30.32	50	58	40	.2120	.60	.00		.85	SE	197	Clear	$\sqcap^0$
25	30.23	55	66	43	.2510	.58	.00		.97	SE	141	Clear	
26	30.24	51	61	44	.2880	.78	.00		.50	N	160	Clear	⊖
27	30.36	39	52	36	.1870	.72	.05	T	.00	N	230	Cloudy	*
28	30.27	44	47	39	.1720	.61	.00		.00	N	95	Cloudy	
29	30.17	47	49	43	.2030	.64	.00		.00	W	71	Cloudy	
30	29.98	50	54	46	.2880	.81	.19		.00	SE	172	Cloudy	$\equiv^2$
31	30.12	47	52	44	.2290	.71	.00		.30	NW	203	Cloudy	
	29.99	57^8	65^5	50^3	.3493	.70	2.81	T	.45	N	5472		

NOVEMBER 1911.

Date	Mean Atmospheric Pressure	Mean Temperature °F°	Maximum Temperature °F°	Minimum Temperature °F°	Mean Vapor Pressure in Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.46	37°	48°	32°	.1233	.54	.00	.00	.70	NW	283	P.Cl.	$\sqcap^{2}$
2	30.79	29	36	22	.1014	.64	.00	.00	1.00	N	197	Clear	Killing frost
3	30.52	35	38	29	.1035	.51	.00	.00	.00	SE	174	Cloudy	
4	30.24	42	45	37	.1490	.57	.00	.00	.00	SE	149	Cloudy	
5	30.10	44	47	40	.2430	.90	.40	.00	.00	SE	252	Cloudy	$\equiv^{2}$ ↯
6	29.65	54	60	44	.2950	.71	.45	.00	.33	W	283	P.Cl.	
7	30.06	48	56	43	.2090	.65	.00	.00	1.00	NW	167	Clear	◒
8	29.89	49	55	43	.2110	.62	.00	.00	.66	SE	255	Clear	
9	29.74	51	55	43	.3540	.87	T	.00	.15	SE	268	Cloudy	
10	29.91	62	67	54	.4550	.83	.00	.00	.60	SE	315	P.Cl.	◒ ⌓^{2}
11	29.85	61	77	39	.4560	.90	.50	.00	.25	SE	520	Cloudy	$\blacktriangle^{0}$ $\triangle^{1}$ ꓘ
12	30.35	18	39	13	.0427	.57	.15	.20	.68	N	531	Clear	◒
13	30.41	24	31	16	.0612	.48	.00	.00	.42	SE	211	P.Cl.	$\sqcap^{2}$
14	29.78	40	47	28	.1134	.45	T	.00	.61	SE	237	P.Cl.	● ▲
15	29.94	41	52	35	.1600	.62	.00	.00	.85	N	170	Clear	$\equiv^{2}$
16	30.01	41	50	30	.1740	.67	.00	.00	.66	SE	352	P.Cl.	
17	29.61	44	62	34	.2370	.76	.75	.00	.00	W	437	Cloudy	ꓘ
18	29.91	38	41	31	.1570	.68	.00	.00	.25	W	263	Cloudy	$\sqcap^{1}$
19	30.09	40	45	35	.1930	.78	.02	T	.08	W	191	Cloudy	
20	30.24	43	47	40	.1560	.61	.00	.00	.08	NW	254	Cloudy	
21	30.24	38	45	31	.1370	.61	.00	.00	.65	N	166	Clear	$\sqcap^{1}$
22	30.03	43	52	34	.1640	.60	.10	.00	.33	SE	311	Cloudy	
23	30.10	30	46	25	.1153	.69	.50	.00	.00	NW	303	Cloudy	
24	30.30	26	32	19	.0970	.71	.00	.01	.75	W	251	Clear	
25	30.08	39	47	27	.1137	.49	.00	.00	1.00	W	169	Clear	
26	29.91	52	64	39	.1480	.40	.00	.00	1.00	SW	205	Clear	
27	29.79	44	55	40	.1800	.63	.27	.00	.37	SE	217	Cloudy	
28	29.99	23	42	20	.0971	.80	.28	.12	.00	NW	452	Cloudy	
29	30.31	18	24	13	.0725	.79	.00	.01	.75	W	258	Clear	
30	30.20	34	41	20	.0930	.48	.00	.00	.70	W	226	P.Cl.	
	30.08	39^{6}	48^{2}	31^{9}	.1741	.65	3.42	.34	.46	SE	8067		

DECEMBER 1911.

Date	Mean Atmospheric Pressure	Mean Temperature F°	Maximum Temperature F°	Minimum Temperature F°	Mean Vapor Pressure In Inches	Mean Relative Humidity	Rain in Inches	Melted Snow in Inches	Sunshine	Prevailing Direction	Total Mileage	Character of Day	Miscellaneous Phenomena
1	30.08	43°	50°	33°	.1670	.61	.00	.00	.60	W	228	P.Cl.	
2	30.15	41	51	33	.1550	.60	.00	.00	.80	W	152	Clear	
3	30.24	33	47	31	.1118	.59	.00	T	.10	N	362	Cloudy	
4	30.47	33	38	26	.1144	.64	.00	.00	.60	SE	163	Clear	≡^{1}
5	30.32	38	45	29	.1230	.56	.00	.00	.80	SE	206	Clear	≡^{1}
6	30.22	44	54	33	.1530	.55	.00	.00	.65	SE	200	P.Cl.	≡^{1}
7	30.19	50	56	41	.2390	.68	.00	.00	.18	SE	156	Cloudy	≡^{1} ⊕
8	30.17	53	58	45	.3320	.83	.03	.00	.12	S	165	Cloudy	
9	30.02	56	60	53	.4020	.89	.03	.00	.00	SE	231	Cloudy	≡^{2}
10	29.75	58	65	51	.3480	.74	.32	.00	.30	SW	389	Cloudy	
11	30.06	44	51	41	.2140	.75	.03	.00	.06	N	131	Cloudy	
12	30.15	37	44	33	.1700	.79	.00	.00	.35	N	156	P.Cl.	
13	30.22	30	36	27	.1660	1.00	.00	.00	.00	SE	57	Cloudy	≡^{2}⊓^{2}
14	30.02	34	36	27	.1790	.90	.00	.00	.00	N	122	Cloudy	⊓^{2}
15	29.92	37	40	34	.1600	.73	T	.00	.00	N	124	Cloudy	Δ
16	29.96	32	39	31	.1670	.91	.06	.50	.00	NW	251	Cloudy	Δ
17	30.25	34	37	30	.1640	.83	.00	.00	.01	SE	134	Cloudy	
18	30.42	38	46	30	.1730	.73	.00	.00	.35	SE	137	P.Cl.	≡^{1}⊓^{2}
19	30.34	36	42	30	.1590	.77	.00	.00	.30	E	160	P.Cl.	
20	29.85	38	40	34	.2000	.87	.26	.00	.00	SE	372	Cloudy	≡^{1}
21	29.95	45	49	37	.1930	.66	.00	.00	.60	S	200	P.Cl.	
22	29.90	40	46	38	.1750	.70	.00	.00	.12	W	156	Cloudy	
23	29.90	33	39	29	.1350	.73	.00	.00	.10	W	170	Cloudy	⊓^{2}
24	29.89	40	48	32	.1430	.58	.00	.00	1.00	SE	228	Clear	
25	30.10	36	42	34	.1850	.88	T	.00	.00	N	136	Cloudy	
26	29.61	40	47	35	.2200	.86	.27	.00	.00	SE	302	Cloudy	≡^{2}
27	30.22	24	36	21	.0830	.86	.00	T	.37	W	464	P.Cl.	
28	30.47	24	31	15	.0725	.58	.00	.00	1.00	SE	236	Clear	
29	30.22	35	39	28	.1489	.71	.01	.00	.00	SE	234	Cloudy	
30	29.92	38	41	35	.2210	.96	.26	.00	.00	SE	135	Cloudy	
31	30.09	18	40	11	.0588	.82	.00	.01	1.00	W	409	Clear	
	30.10	38	45	32^{8}	.1785	.72	1.27	.51	.38	SE	6586		

MONTHLY AND ANNUAL METEOROLOGICAL SUMMARY 1911.

	Atmospheric Pressure			Temperature					Moisture		Precipitation		Wind		Weather				Miscellaneous Phenomena								
	Mean	Highest	Lowest	Maximum	Minimum	Mean Maximum	Mean Minimum	Monthly Mean	Mean Vapor Pressure	Relative Humidity	Rain	Melted Snow	Prevailing Direction	Total Mileage	Average Daily Sunshine	Number of Clear Days	Number of Cloudy Days	Partly Cloudy Days	Solar Halos	Lunar Halos	Thunderstorms	Hail	Sleet	Fog	Frost	Killing Frost	Date of Killing Frost
JANUARY	30.14	30.59	29.66	73	-2	45.5	27.6	36.3	.1672	.68	1.05	.17	S	7045	.45	6	19	6	0	1	1	1	4	2	1	None in Spring	
FEBRUARY	30.13	30.66	29.49	83	15	47.6	31.3	39.0	.1725	.67	1.93	1.93	W	6859	.56	12	13	3	2	3	1	0	2	1	1		
MARCH	30.01	30.47	29.45	80	21	58.5	36.2	46.6	.1842	.57	2.01	.42	SE	7937	.68	16	6	9	0	1	2	1	1	1	2		
APRIL	30.00	30.47	29.34	75	33	63.3	45.6	55.0	.2663	.61	6.92	0.00	SE	7035	.53	11	14	5	3	2	6	3	0	3	0		
MAY	29.97	30.35	29.51	94	37	76.8	61.0	72.8	.4373	.53	1.85	T	S	5740	.81	17	2	12	1	1	4	1	0	5	0		
JUNE	29.88	30.07	29.61	99	62	90.0	70.0	81.0	.5919	.57	1.79	0.00	S	5273	.75	15	7	8	0	0	7	0	0	0	0		
JULY	29.94	30.16	29.60	101	56	89.0	70.0	80.9	.5667	.55	0.74	0.00	S	5356	.74	13	6	12	0	0	2	0	0	1	0		
AUGUST	29.93	30.14	29.76	96	52	85.0	67.0	76.7	.6062	.66	4.72	0.00	SE	4556	.60	14	9	8	0	0	6	0	0	3	0		
SEPTEMBER	29.98	30.19	29.78	95	55	83.7	66.0	74.7	.6315	.73	7.30	0.00	SE	4795	.56	11	7	12	0	1	12	0	0	5	0		
OCTOBER	29.99	30.40	29.64	89	36	65.5	50.3	57.3	.3493	.70	2.81	T	N	5472	.45	10	16	5	1	0	3	0	0	6	2		
NOVEMBER	30.08	30.82	29.26	77	13	48.2	31.9	39.6	.1741	.65	3.42	0.34	SE	8067	.46	10	13	7	1	3	2	1	2	2	5	NOV	2
DECEMBER	30.10	30.54	29.52	65	11	45.0	32.5	38.0	.1785	.72	1.27	0.51	SE	6586	.38	6	18	7	0	1	0	0	2	9	3		
ANNUAL	30.01	30.82	29.26	101	-2	66.0	48.0	58.0	.3605	.64	35.84	3.10	SE	74621	.58	141	130	94	8	13	46	7	11	38	14		

Seismology in St. Louis University.

PART II.

During the year 1911 the Seismological Department was conducted, as in the preceding year, along the lines sketched in the December Bulletin of the St. Louis University.[1] Hence we respectfully refer our readers to that publication for a discussion of our instrument and methods, as the present report will be supplementary to it.

The earthquakes registered during the year were thirty-seven in number, as tabulated further on. Among these, two are especially worthy of further study. The earthquakes of June 7th and December 16th are both said to have caused considerable damage throughout the central portion of the Republic of Mexico. A comparison of the seismograms, however, reveals decided differences. Hence it will be of the greatest interest to determine as accurately as possible the position of the two epicenters. To this end we made use of each of the three methods now in vogue, that of Prince Galitzin,[2] that of Dr. Klotz, to which we referred in the December Bulletin, and the least square method applied by Dr. Geiger.[3]

THE METHOD OF PRINCE GALITZIN.

The method of Prince Galitzin consists in reducing the first maximum amplitude of the P-waves, which appears on the record of each component to the corresponding earth-motion amplitudes (A_E and A_N), and applying the formula: $\tan x = \frac{A_E}{A_N}$, in which x is the angle of azimuth. In this formula we give the positive sign to an earth-displacement toward the north or east, and the negative sign to a displacement toward the south or west. The arrows on the seismogram for December 16th indicate the corresponding displacements of the pen on our seismograph when the inertia of the pendulum and pillar does not come into play, as would be the case in very rapid oscillations. Since the first preliminary waves are longitudinal, they must of necessity impinge upon the seismograph in a line parallel to the direction of motion of the wave front; and, if the components are properly recorded, this line will be indicated by the seismograph. But the *direction* of the impulse communicated by the wave-front will be toward the epicenter or away from it according as the wave is *dilatational* or *condensational,* that is, a *contraction toward the hypocenter or an outward compression away from it,* as Prince Galitzin has well pointed out. This ambiguity is at once removed by noting whether the vertical component is upward, as would be the case in a condensation wave, or downward, as in a dilatation wave. If the latter is true, then the epicenter lies in the opposite direction from that indicated by the seismograph. Prince Galitzin has demonstrated to evidence that this method of locating epicenters is capable of great accuracy when applied, with proper precautions, to the records of his specially designed aperiodic pendulums with photo-galvanometric registration. To what extent it may be relied upon in the case of a small machine like ours with all its friction may be seen from the following results. The constants of our Wiechert 80 kg. horizontal seismograph, as determined June 6th, the day before the first of the two Mexican earthquakes, were: T_0E = 7 sec., T_0N = 7 sec., VE = 67, VN = 79. Taking the first impulse which appears on both components, the respective amplitudes reduced to earth motion, were: AE = 7.8 μ, AN = 67.9 μ, which give an azimuth for the epicenter = tan^{-1} .1149 = S 6° 33′ W. Taking this value together with the distance Δ = 2600 km., and solving the corresponding spherical triangle, we obtain as co-ordinates of the epicenter: ϕ = 15°.3 N, λ = 92°.9 W. As a check on this result we do the same for the first impulse in the reflection 24 sec. later and obtain as azimuth S 17° 6′ W. This gives us as co-ordinates: ϕ = 16°.1 N, λ = 97°.2 W. Prince Galitzin obtained by his method from the observations of Pulkowa, ϕ = 19° 34′ N, λ = 97° 59′ W.[4]

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[1] *Seismology in St. Louis University*, Bulletin, Vol. VII, No. 5, December, 1911.

[2] *Bestimmung der Lage des Epicentrums eines Bebens aus den Angaben einer einzelnen Station*, St. Petersburg, 1911.

[3] Dr. L. Geiger.—*Herdbestimmung bei Erdbeben aus den Ankunftszeiten*, Goettingen, 1910.

The constants for December 16th, as determined the following day, were: = T_0E = 6.8 sec., T_0N = 7 sec., VE = 88, VN = 83. The earth amplitudes of the initial impulse were: AE = 12.5 μ, AN = 22.7 μ. This gives as azimuth S 28° 50′ W. Taking the distance as 2690 km., we obtain as co-ordinates: ϕ = 16°.8 N, λ = 102°.9 W. However, if we take as horizontal components the average maximum amplitude of several of the waves immediately following the initial impulse, we obtain as azimuth S 18° 26′ W. This places the epicenter at $\phi = 15^\circ.4$ N, $\lambda = 98^\circ$ W.

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[4] Op. cit. See Note 3.

Dr. Tams obtained from the observations of Hamburg, by the same method: $\phi = 16^\circ$ N, $\lambda = 97^\circ$ W.[5]

By another method Dr. Zeissig obtained as co-ordinates: $\phi = 15^\circ.6$ N, $\lambda = 96^\circ.4$ W.

It will be seen from these results that the Galitzin method, even with a small machine like ours, will give a very fair approximation.

STEREOGRAPHIC METHOD OF DR. KLOTZ.

Applying the method of Dr. Klotz[6] to the earthquake of June 7, we obtain three approximate intersections of three circles. (Fig. 1.)

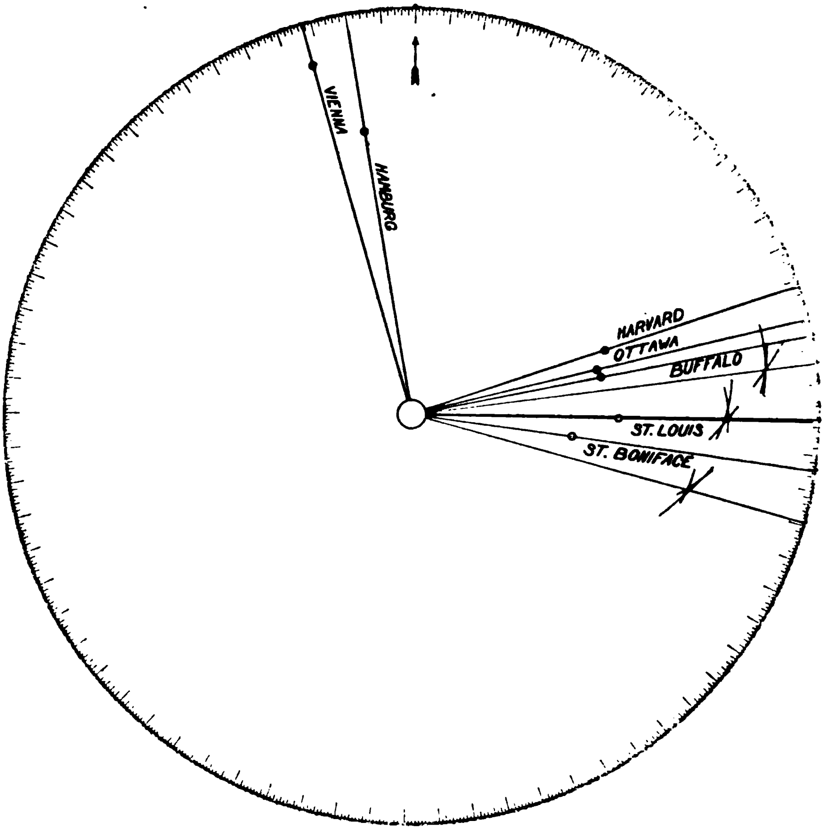

Fig. 1.

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[5] *Mitteilungen*, No. 44.

[6] Dr. Otto Klotz, F. R. A. S.—*Earthquake Epicenters.* Journal of the Astronomical Society of Canada, May-June, 1910.

The lower intersection determined by data from Hamburg, Harvard and St. Boniface places the epicenter at λ = 104°.6 W, φ = 19°.8 N. The middle one, from Vienna, Buffalo and St. Louis, gives λ = 89°.9 W, φ = 14°.5 N. According to the upper one, due to Vienna, Ottawa and Harvard, λ = 82° W and φ = 7°.7 N.

Applying the method to the earthquake of Dec. 16, we obtain but one intersection of three circles, as seen in Fig. 2. This would place the epicenter at λ = 95° W, φ = 15° N.

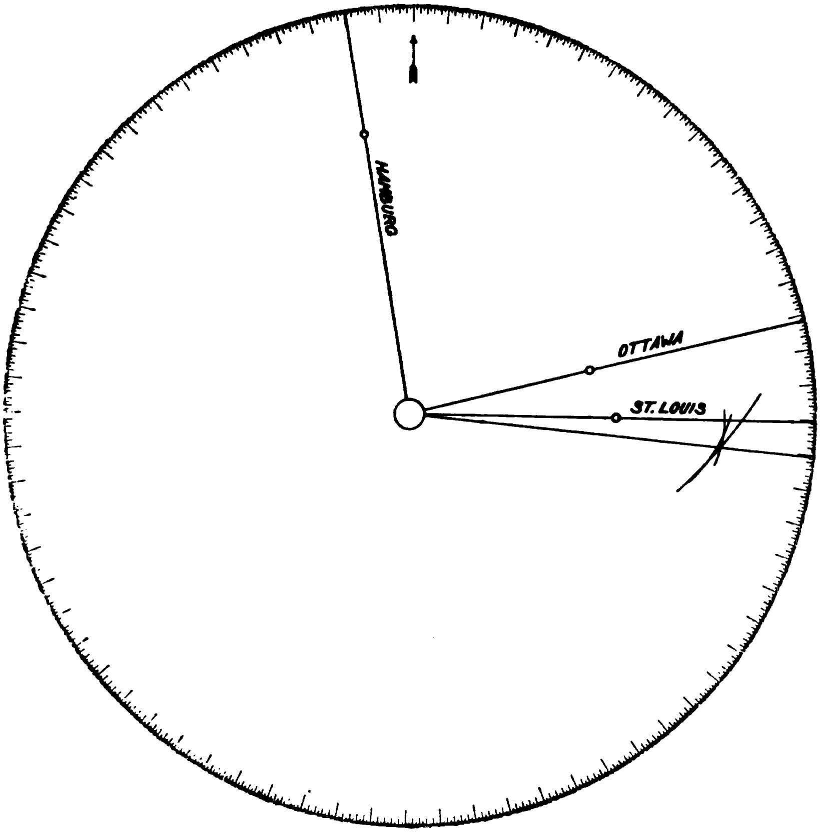

FIg. 2.

The discrepancies which appear in the values thus obtained for the epicenter of the June earthquake would seem to indicate that the epicentric area was of considerable extent. A further reason for suspecting this may be found in the fact that, though the epicenter was evidently somewhere beneath the Pacific, the whole of Central Mexico was included in the megaseismic district. In order to ascertain what point was probably nearest the center of the epicentric area we may now apply the method of Dr. Geiger.[7]

PROBABILITY METHOD FOR THE DETERMINATION OF EARTHQUAKE EPICENTERS FROM THE ARRIVAL TIME ONLY.

Nomenclature: λ = longitude, ϕ = latitude, t = time in hours, minutes and seconds of an occurrence. T = a period of time in minutes and seconds for wave translation. * indicates that the accompanying value is assumed, subject to correction. Δ is angular distance on the earth's surface. † is used but once, and indicates observation, and as attached to time means observation time of arrival at a station. Numeral subscripts and the general subscript $_n$ designate the station data, either assumed or absolute. Subscript $_0$ indicates an epicentric function.

To make use of this third method, we must first assume an approximate location of the epicenter, and the closer this assumption is to the ultimate location the smaller will be the corrections and the more accurate the work; but a very fair localization may be computed with an error of several degrees in the first assumption. The process depends to a great extent on the translation time of the first preliminaries, which is, of course, not a linear function of the distance.

If we assume $^*\lambda_0$, $^*\phi_0$ and $^*t_0$ by any convenient method, and assume that in each there is an error which we will designate by $\delta^*\lambda_0$, by $\delta^*\phi_0$ and by δ^*t_0, equation (1) follows:

$$\lambda_0 = {}^*\lambda_0 + \delta^*\lambda_0$$
$$\phi_0 = {}^*\phi_0 + \delta^*\phi_0 \text{ and } t_0 = {}^*t_0 + \delta^*t_0$$

In these equations the left-hand members are the ones primarily sought, and the first terms of the right-hand members are unvarying assumed quantities subject to variation by their second terms, which are the corrections. Here the case resolves itself into a determination of the δ quantities. To determine these we proceed as follows:

We first calculate the distance from the assumed epicenter to each station, by means of the spherical cosine law:

$$\text{Cos } \Delta_n = \sin \phi_0 \sin \phi_n + \cos \phi_0 \cos \phi_n \cos (\lambda_0 - \lambda_n) \quad . \qquad (2)$$

In our tabular work at the end of the discussion this is done logarithmically, and the two terms of the right-hand member of the cosine law are designated by I and II. These are to be added. After obtaining in this way cos $^*\Delta_n$, the corresponding $^*\Delta_n$ in angular measurement is taken from a table of natural cosines.

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[7] See Note 4.

Having now the angular or arcual distance approximately, from station $_n$ to an assumed location of the epicenter, we take from Table 1[8] an approximate translation time. This translation time is called, according to our symbols, $^*T_n$. An approximate translation time added to an approximate occurrence time will give an approximate arrival time, *i. e.*—

$$^*t_n = {}^*t_0 + {}^*T_n \quad . \quad . \quad . \quad (3)$$

Were there no error in our assumed location, and no error in recorded times, and no error in observation, this $^*t_n$ would be our observation time, $^\dagger t_n$. But there are errors, so that there will be a difference, F_n, between the two, *i. e.*—

$$F_n = {}^*t_n - {}^\dagger t_n \quad . \quad . \quad . \quad (4)$$

The foregoing makes it clear that if there were no errors such as $\delta^*\lambda_0$, $\delta^*\phi_0$ and δ^*t_0, and the $^\dagger t_n$ were accurate, there could be no F_n.

Our next step is to establish a relationship between F_n and the errors in assumption which occasion its existence.

Assuming for the moment that all data were correct for location and time at the epicenter except the longitude, and that an F_n existed because of a difference in longitudes, then

$$F_n = \delta^*\lambda_0 \frac{\delta^*t_n}{\delta^*\lambda_0},$$

that is, F_n would be a time correction equal to the time correction per unit of longitude, multiplied by the number of units of longitude correction. If we were to examine the rate of change in translation time per degree of longitude, and with this ratio correct our time by an amount equal to that ratio multiplied by the actual longitude correction in the same units, this would satisfy F_n in so far as the longitude variation is concerned. Now, all that has been said about longitude will apply with equal force to latitude independently, and we shall have $\delta^*\phi_0\ (\delta^*t_n/\delta^*\phi_0)$. On the other hand, if we suppose a change in time of occurrence, $^*t_0$, there must be a similar change in time of arrival, $^*t_n$, so that the rate of change of arrival time with respect to occurrence time, δ^*t_n/δ^*t_0, is always unity. In order, however, to handle the matter mathematically this time ratio is treated as are the others, and hence a third correction appears as $\delta^*t_0\ (\delta^*t_n/\delta^*t_0)$, though its value is merely δ^*t_0. From this consideration it follows that F_n is essentially a differential by existence, for it may be equated to differentials as has been done above; and hence approaches 0 as a limit when δ-terms are made indefinitely small. Now it may be shown by Taylor's Theorem that if F_n depend separately upon $(\delta^* t_n/\delta^*\lambda_0)\ \delta^*\lambda_0$, $(\delta^* t_n/\delta^*\phi_0)\ \delta^*\phi_0$, and $(\delta^* t_n/\delta^* t_0)\ \delta^* t_0$, it may be equated to their sum. In forming this equation, the partial differential sign, ∂, replaces δ in the ratio to indicate that each is treated as if the others were constants and that in the end the sum total is used. In our work tabulated later it will be seen that this is exactly followed out with respect to latitude and longitude, and the same would have been done with respect to time, but for the fact that the time ratio is everywhere equal to 1, and hence would only have introduced useless work.

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[8] Taken from Dr. L. Geiger's *Herdbestimmung.* See Note 4.

$$\text{Therefore } F_n = \frac{\partial^* t_n}{\partial^*\lambda_0}.\,\delta^*\lambda_0 + \frac{\partial^* t_n}{\partial^*\phi_0}.\,\delta^*\phi_0 + \frac{\partial^* t_n}{\partial^* t_0}.\,\delta^* t_0 \quad . \quad . \qquad (5)$$

From relations established in (3) it follows that any increment given to $^* t_n$ will have to be given to $^* T_n$, otherwise the translation time would be a variable with the hour of the day, so that $\partial^* T_n$ may replace $\partial^* t_n$ in any ratios.

Therefore we may substitute in (5)

$$F_n = \frac{\partial^* T_n}{\partial^*\lambda_0}.\,\delta^*\lambda_0 + \frac{\partial^* T_n}{\partial\phi_0}.\,\delta^*\phi_0 + \delta^* t_0 \quad . \quad . \qquad (6)$$

By replacing the ratios in (6) with a_n, b_n and c_n, and remembering that c_n must be $= 1$, we obtain at once

$$F_n = a_n\,\delta^*\lambda_0 + b_n\,\delta^*\phi_0 + c_n.\ \delta^* t_0 \quad . \quad . \qquad (7)$$

After equation (6) we placed $a_n = \dfrac{\partial^* T_n}{\partial^*\lambda_0}$, $b_n = \dfrac{\partial^* T_n}{\partial^*\phi_0}$. Introducing now $\partial^*\Delta_n$ in both numerator and denominator of each of these ratios, and factoring the resulting fraction, we get:

$$a_n = \frac{\partial^* T_n}{\partial^*\Delta_n}.\frac{\partial^*\Delta_n}{\partial^*\lambda_0} \quad \text{and} \quad b_n = \frac{\partial^* T_n}{\partial^*\Delta_n}.\frac{\partial^*\Delta_n}{\partial^*\phi_0} \quad . \quad . \qquad (8)$$

Now, if we reckon $\partial^* T_n$ in seconds of time and $\partial^*\Delta_n$ in minutes of arc, the first ratio in the above will express the difference in the translation time per minute of arc change in the $^*\Delta_n$. This may be calculated from Table I as follows: Take the time difference, d^*_n, for each station in seconds corresponding to a change of one degree at the given distance, ${}^*\Delta_n$, and divide it by 60 to obtain the time difference for 1′.

$$\text{Thus, } \frac{\partial^* T_n}{\partial^* \Delta_n} = \frac{d^s{}_n}{60'} \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

The second ratio in each case will obviously be the quotient of the change produced in the distance, ${}^*\Delta_n$, by giving an increment to the longitude or latitude of the assumed epicenter, divided by that increment, that is, the change in ${}^*\Delta_n$ per unit change in ${}^*\lambda_0$ or ${}^*\phi_0$. This ratio may readily be obtained in the following manner: Assign an arbitrary increment, $\delta^*\lambda_0$, say of 1° or more, to the longitude of the assumed epicenter. The co-ordinates of this new point will be $[({}^*\lambda_0 + \delta^*\lambda_0), {}^*\phi_0]$. By means of the spherical cosine law, (2), calculate the distance from each station to that point. Call this distance ${}^*\Delta_n\lambda$. Then, evidently, ${}^*\Delta_n\lambda - {}^*\Delta_n = \delta^*\Delta_n$, the change produced in ${}^*\Delta_n$ by assigning the increment to ${}^*\Delta_0$. Divide this total change, $\delta^*\Delta_n$, by the increment assigned to ${}^*\lambda_0$, and the quotient will be the approximate change in ${}^*\Delta_n$ per unit change in ${}^*\lambda_0$, which is the desired ratio, $\partial^*\Delta_n/\partial^*\lambda_0$. The products of $\partial^*\Delta_n/\partial^*\lambda_0$ and $d^s{}_n/60'$ for each station (8) will give the coefficient a_n in (7).

Proceeding in a similar way to obtain

$$\frac{\partial^*\Delta_n}{\partial^*\phi_0},$$

we assign the same arbitrary increment of 1° or more to ${}^*\phi_0$, calculate the distance, ${}^*\Delta_n\phi$, from each station to the new point, $[{}^*\lambda_0, ({}^*\phi_0 + \delta^*\phi_0)]$, find the difference ${}^*\Delta_n\phi - {}^*\Delta_n$, and divide it by the latitude increment $\delta^*\phi_0$. The result will again be the desired ratio $\partial^*\Delta_n/\partial^*\phi_0$, which, when multiplied by the interpolation factor $d^s{}_n/60'$ from (9) will give the second coefficient b_n in (7). This work will be found tabulated with ${}^*\Delta_n$, the distance from each station to the assumed epicenter, in Table 2.

We have now real numerical values for a_n and b_n as well as for $c_n = 1$. But $_n$ denotes any one of the stations, so that by (7) we see that we have an F-value, F_n, for each station. Thus we have as many error equations as there are stations whose data we used. Now it is shown in the theory[9] of the least square method, that the most probable values of the required unknowns are those which will make the sum of the squares of the single errors a minimum. Let x be some quantity which added to each of the assumed errors will make the sum of the squares of the resulting quantities, $(F_1 + x)^2 + (F_2{}^2 + x)^2 + \quad . \quad . \quad + (F_n + x)^2$, a minimum.

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[9] For proofs the reader may consult:
Bartlett, *Method of Least Squares;*
Merriman, *Method of Least Squares*, New York, 1884;
Woodward, *Geographical Tables*, Smith. Inst. Publ., 1894;
Doolittle, *Practical Astronomy, 5th Ed.*, 1910;
Helmert, *Ausgleichungsrechnung nach der Methode der kleinsten Quadrate, 2 Aufl.* 1907.

Then it follows from the Calculus that, as the function under consideration tends toward a minimum and not a maximum, that value of x will make the function a minimum which will make the first derivative equal to 0. Therefore differentiating, equating to 0 and solving for x, we obtain the correction which must be added to each station error so as to make the mean error a minimum. Our general error equation now becomes:

$$(F_n + x) = a_n\delta^*\lambda_0 + b_n\delta^*\phi_0 + c_n\delta^*t_0 \quad . \quad . \quad (10)$$

This gives the greatest weight to those stations whose observations most nearly agree, and least weight to those whose error differs most from the mean. Each of the three unknown quantities will have thus to adjust themselves to that value which will give the least mean error. We now tabulate as in Table 3, the numerical values of the three coefficients a, b and c, and their sum S, which will be needed in further work, together with the "weighted error" $(F + x)$ for each station. This latter value, $(F + x)_n$, we shall call simply F_n. For convenience also we shall set the first unknown $\delta^*\lambda_0 = x$; the second, $\delta^*\phi_0 = y$; and the third, $\delta^*t_0 = z$. We are now ready to form and to solve the so-called normal equations.

FORMATION AND SOLUTION OF THE NORMAL EQUATIONS.

If there be a given number of simultaneous equations and that number is in excess of the number of unknowns, as in our case, then, in attempting a solution, it may be impossible to justify all the results obtained on account of inaccuracies in the original data. The values of the quantities depend upon the values of the coefficients and if it be possible to adjust these to a most probable value for each, then one result for each unknown may be obtained. For most physical purposes, where the best result that can be obtained is an approximation, such a proceeding is very useful. The method, with an arrangement of detached coefficients, is as follows:

We are given the following five equations:

$$\begin{aligned} a_1x + b_1y + c_1z &= F_1 \\ a_2x + b_2y + c_2z &= F_2 \\ a_3x + b_3y + c_3z &= F_3 \\ a_4x + b_4y + c_4z &= F_4 \\ a_5x + b_5y + c_5z &= F_5 \end{aligned}$$

From these we are to find the value of the three unknown quantities. If the five equations are added term by term an equality will remain and may be written, $[a]x + [b]y + [c]z = [F]$, in which the sign [ ] means simply that the term enclosed by it is a sum of all such quantities.

This single equation will give one in which the inaccuracies are averaged and, if the errors are equal, or if equal reliance may be placed on each element of the data, it is the most reasonable approximation that we can select.

The one equation given above will not suffice for the solution of the three unknowns, so a method must be given that will provide at least three equations. If, before making the addition above, each of the N equations had been multiplied by a_n, where $_n$ is a general subscript, our sum would have been, by the notation that we are using,

$[aa]x + [ab]y + [ac]z = [aF]$ and similarly multiplying by b_n
$[ab]x + [bb]y + [bc]z = [bF]$ and similarly multiplying by c_n
$[ac]x + [bc]y + [cc]z = [bF]$.

These are known as normal equations and are treated as any other simultaneous equations. There are but three of them for a solution of three unknowns, so that there can be no interference from a number of different answers. In other words, we have averaged our error before the computation began.

In the following work we will omit, for the greater part, the sign [ ], which means the sum of all such terms as are enclosed by it, though account of it must be made. We need:

$$\begin{array}{cccc} aa & ab & ac & aF \\ & bb & bc & bF \\ & & cc & cF \\ & & & FF \end{array}$$

From these we calculate, $bb - \frac{ab}{aa} . ab = bb_1$

$$bc - \frac{ab}{aa} . ac = bc_1$$

$$bF - \frac{ab}{aa} . aF = bF_1$$

$$cc - \frac{ac}{aa} . ac = cc_1$$

$$cF - \frac{ac}{aa} . aF = cF_1$$

And from these in turn,

$$cc_1 - \frac{bc_1}{bb_1} . bc_1 = cc_2$$

$$cF_1 - \frac{bc_1}{bb_1} . bF_1 = cF_2$$

In order to check the numerical work from time to time an independent calculation is carried on. This independent work has enough totals in common with the regular work to be of service as a check, but the determination should be carried out as above, with the following as a check and nothing else:

Let $a + b + c = S$

$$a_1S_1 + b_2S_2 + a_3S_3 \ . \ . \ . \ a_nS_n = aS$$
$$b_1S_1 + b_2S_2 + b_3S_3 \ . \ . \ . \ b_nS_n = bS$$
etc.

Then

$$aa + ab + ac = aS$$
$$ab + bb + bc = bS$$
$$ac + bc + cc = cS$$
$$aF + bF + cF = FS$$

From this we can calculate

$bS - \frac{ab}{aa}.aS = bS_1$, and it follows that $bS_1 = bb_1 + bc_1$, which checks two of our other determinations.

$$cS - \frac{ac}{aa}.aS = cS_1 \text{ and so } cS_1 = bc_1 + cc_1$$

$$FS - \frac{aF}{aa}.aS = FS_1 \text{ and so } FS_1 = bF_1 + cF_1$$

And, furthermore, $cS_1 - \frac{bc_1}{bb_1}.bS_1 = cS_2$ and $cS_2 = cc_2$

$$FS_1 - \frac{bF_1}{bb_1}.bS_1 = FS_2 \text{ and } FS_2 = cF_2$$

As a matter of final check we return to our original equations like, $a_1x + b_1y + c_1z = F$, and substitute, when the real error will appear. We will proceed with the solution of the general case.

(1) $aax + aby + acz = aF$
(2) $abx + bby + bcz = bF$
(3) $acx + bcy + ccz = cF$.

Eliminating x from (1) and (2) we have:

$$aa.abx + ab.aby + ab.acz = ab.aF$$
$$aa.abx + aa.bby + aa.bcz = aa.bF$$

Subtracting the one from the other and dividing by aa, we obtain:

$$(4)\quad (bb - \frac{ab}{aa}.ab)\,y + (bc - \frac{ab}{aa}.ac)\,z = (bF - \frac{ab}{aa}.aF)$$

Transforming by substitution, we have:

(5) $bb_1y + bc_1z = bF_1$

Eliminating x from (1) and (3) we have:

$aa.acx + ab.acy + ac.acz = ac.aF$

$aa.acx + aa.bcy + aa.ccz = aa.cF$. By repeating the subtraction, division by aa, and the transforming by substitution, we also have

(6) $bc_1y + cc_1z = cF_1$, in which bc_1 is the same as in (5).

Eliminating y from (5) and (6),

$$\begin{aligned} bb_1y + bc_1z = bF_1 &= (bb_1.bc_1)y + (bc_1.bc_1)z = bc_1bF_1 \\ bc_1y + cc_1z = cF_1 &= (bb_1.bc_1)y + (bb_1.cc_1)z = bb_1cF_1 \\ (bc_1.bc_1 - bb_1.cc_1)z &= (bc_1bF_1 - bb_1.cF_1) \end{aligned}$$

Dividing by $-bb_1$. transforming and substituting, we obtain:

$$(7)\quad cc_2z = cF_2$$

$$(8)\quad z = \frac{cF_2}{cc_2}$$

Substituting z in (5) and transposing, we obtain:

$$(9)\quad y = \frac{bF_1}{bb_1}. - \frac{bc_1}{bb_1}. z$$

Evaluating (1) for x we have:

$$(10)\quad x = \frac{aF}{aa} - \frac{ab}{aa}y - \frac{ac}{aa}z.$$

Substituting for x, y and z, their original symbols $\delta^*\lambda_0$, $\delta^*\phi_0$, δ^*t_0, and replacing these in equation (1) by the values here found, we obtain the co-ordinates of the corrected epicenter, λ_0, ϕ_0 and t_0. By the method of detached coefficients outlined above, the value of the three unknowns may be calculated directly, without solving the simultaneous equations, by substituting the required coefficients in the final formulas.

As a final check on the entire calculation we substitute the values of $\delta^*\lambda_0$, $\delta^*\phi_0$ and δ^*t_0 in each of the N error equations, and thus obtain the N "error corrections."

$$f_n = a_n\delta^*\lambda_0 + b_n\delta^*\phi_0 + c_n\delta^*t_0 - F_n \quad . \quad . \qquad (11)$$

The sum of these "error corrections" must then be:

$$ff = FF - \frac{aF}{aa}. aF - \frac{bF_1}{bb_1}. bF_1 - \frac{cF_2}{cc_2}. cF_2 \quad . \qquad (12)$$

These quantities will be found in Table 5.

METHOD OF DETERMINING THE ACCURACY ATTAINED.

We should not be satisfied with the values we have obtained for λ_0, ϕ_0 and t_0, without some precision measure to test their accuracy. By this we mean, however, their relative accuracy, for if there be a constant error in the observations of all the stations whose data we have used then there will also be an absolute error in the above quantities, which only new station data will detect. With this distinction clearly in mind we proceed to determine the so-called mean error, $\mu\lambda$, $\mu\phi$ and μt, which is to be feared in the three quantities, λ_0, ϕ_0 and t_0. This Dr. Geiger does in the following way:[10]

First calculate the six coefficients of weight, as they are called, $Q\lambda\lambda$, $Q\phi\phi$, $Q\mathrm{tt}$, $Q\lambda\phi$, $Q\lambda\mathrm{t}$, $Q\phi\mathrm{t}$,

$$Q\lambda\lambda = \frac{bb.cc - bc.bc}{[aa].[bb_1].[cc_2]} = \frac{Z\lambda\lambda}{D}$$

$$Q\phi\phi = \frac{aa.cc - ac.ac}{[aa].[bb_1].[cc_2]} = \frac{Z\phi\phi}{D}$$

$$Q\mathrm{tt} = \frac{aa.bb - ab.ab}{[aa].[bb_1].[cc_2]} = \frac{Z\mathrm{tt}}{D}$$

$$Q\lambda\phi = -\frac{ab.cc - ac.bc}{[aa].[bb_1].[cc_2]} = \frac{Z\lambda\phi}{D}$$

$$Q\lambda t = -\frac{ac.bb - ab.bc}{[aa].[bb_1].[cc_2]} = \frac{Z\lambda\mathrm{t}}{D}$$

$$Q\phi t = -\frac{bc.aa - ab.ac}{[aa].[bb_1].[cc_2]} = \frac{Z\phi\mathrm{t}}{D} \quad . \quad . \quad (13)$$

As a check on these calculations we test the truth of the following:

$$[aS].(Q\lambda\lambda + Q\lambda\phi + Q\lambda t) + [bS].(Q\lambda\phi + Q\phi\phi + Q\phi t)$$
$$+ [cS].(Q\lambda t + Q\phi t + Qtt) = 3 \quad . \quad . \quad . \quad (14)$$

The number 3 is the number of the unknowns. These values will be found in Table 4.

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[10] See Note 4.

Next we need the error of unit weight, μ. This we find by the formula:

$$\mu = \sqrt{\frac{ff}{N\text{-}3}} \quad . \quad . \quad . \quad . \qquad (15)$$

ff being the value obtained in (12), N the number of stations, and 3 the number of unknowns as above. Then the mean errors are:

$$\mu\lambda = \pm\,\mu\sqrt{Q\lambda\lambda},\ \mu\phi = +\,\mu\sqrt{Q\phi\phi},\ \mu t = \pm\,\mu\sqrt{Qtt} \quad . \qquad (16)$$

The relative accuracy of the entire determination may now be graphically characterized by constructing the so-called mean error ellipse. To this end we must first reduce the above longitude and latitude error values to the same absolute units. As the absolute length of a latitude unit is practically invariable, being always measured on great circles, while that of the unit of longitude varies with the cosine of the latitude, it follows that $\mu\phi$, on this basis will remain $\mu\phi$, while $\mu\lambda$ will become $\mu\lambda \cos \phi_0$. So, too, if we denote the coefficient of longitude on itself, reduced to this basis, by Q_{11}, of latitude on itself by Q_{22} and the coefficient of mutual weight by Q_{12}, then it is evident that Q_{22} will be the same as above, $Q\phi\phi$, while Q_{12} will contain $\cos \phi_0$ once as a factor and Q_{11} twice. Hence

$$Q_{11} = Q\lambda\lambda \cos^2\phi_0,\ Q_{12} = Q\lambda\phi \cos \phi_0,\ Q_{22} = Q\phi\phi \quad . \qquad (17)$$

Now the angle ω, at which the longitude semi-axis $\mu\omega_1$, is inclined to the parallel in the Figure 3, is given by the equation

$$\tan 2\omega = \frac{2Q_{12}}{Q_{11} - Q_{22}} \quad . \quad . \quad . \qquad (18)$$

From this we obtain the angle ω_2 at which the latitude semi-axis $\mu\omega_2$ is inclined to the meridian, for evidently

$$\omega_2 = \omega_1 + 90^\circ \quad . \quad . \quad . \quad . \qquad (19)$$

The only values that still remain to be determined are the lengths of the two semi-axis $\mu\omega_1$ and $\mu\omega_2$. These are given by:

$$\begin{aligned} \mu\omega_1 &= +\,\mu\sqrt{Q_{11} + Q_{12} \tan \omega_1} \\ \mu\omega_2 &= +\,\mu\sqrt{Q_{11} + Q_{12} \tan \omega_2} \quad . \quad . \qquad (20) \end{aligned}$$

μ being the error of unit weight from (15).

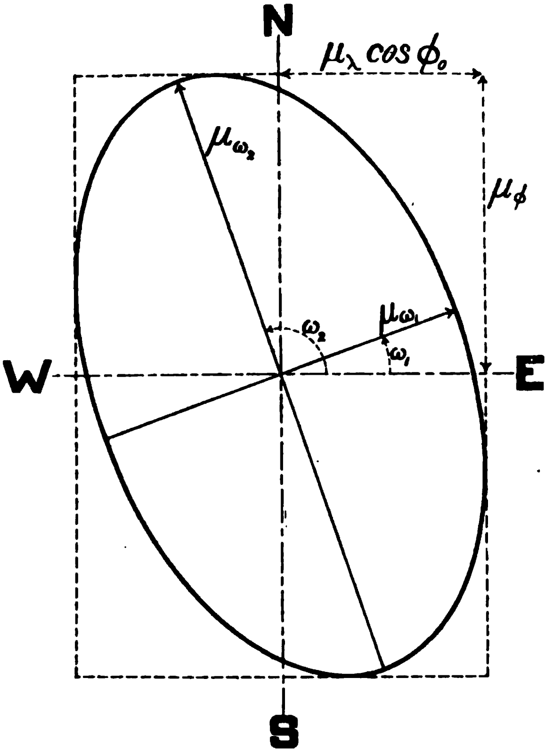


Fig. 3.

The projections of the ellipse on the meridian and parallel, and hence the sides of the tangent quadrangle enclosing the ellipse are $2\mu\phi$ and $2\mu\lambda \cos \phi_0$. The relative probability that the epicenter lies within the ellipse is $1 - \sqrt{e} = 0.393$.

PROBABILITY METHOD APPLIED TO THE EARTHQUAKE OF JUNE 7, 1911.

The first step to be taken in applying this third method is, as we have said, to assume a probable location for the epicenter. Now, in the case of the June 7th earthquake, we shall take as probable coordinates: $\lambda = 103°$ W, $\phi = 19°$ N, which would place the epicenter between $\lambda = 97° \ 59'$ W, $\phi = 19° \ 34'$ N, as given by Prince Galitzin, and $\lambda = 104°.6$ W, $\phi = 19°.8$ N, as obtained from the Hamburg-Harvard-St. Boniface intersection according to the method of Dr. Klotz.

On account of what seems to be a considerable disagreement in the arrival times of stations at a greater distance, we shall choose the following five stations as being close to the earthquake, and still sufficiently scattered for our purpose: Buffalo, Harvard, Ottawa, St. Boniface, Santa Clara, St. Louis.

Place.	Station No.	Longitude.	Latitude.	Arrival Time of P-Waves.
Epicenter	0	103° 00′ 00″	19° 00′ 00″	11 h. 2 m. 32 s.
St. Louis	1	90° 13′ 58″.5	38° 38′ 17″	11 h. 7 m. 46 s.
St. Boniface	2	97° 6′ 39″	49° 53′ 31″	11 h. 9 m. 9 s.
Harvard	3	71° 6′ 59″	42° 22′ 56″	11 h. 9 m. 50 s.
Buffalo	4	78° 52′ 40″	42° 53′ 2″	11 h. 9 m. 9 s.
Santa Clara	5	121° 57′ 3″	37° 26′ 36″	11 h. 8 m. 12 s.
Ottawa	6	75° 42′ 57″	45° 23′ 38″	11 h. 9 m. 43 s.

With these we calculate Table II for each station (of which we give only one example), and Tables III, IV and V. We see from Table IV that the corrected position of the epicenter is: $\lambda_0 = 102° \ 39' + 23'$ W, $\phi = 18° \ 30' \pm 96'$ N. The next step will be to calculate and construct the mean error ellipse about this point as center.

From (17), $Q_{11} = + 36.35$, $Q_{12} = - 68.15$, $Q_{22} = + 682.67$. Hence $\tan 2\omega_1 = + .2087$, $\omega_1 = 5° \ 57'.3$, $\omega_2 = 95° \ 57'.3$ and

$$\mu\omega_1 = 3.66 \ 36.35 - 68.15 \times \ .1043 = 19.9 \text{ Geogr. miles},$$
$$\mu\omega_2 = 3.66 \ 36.35 + 68.15 \times 9.5878 = 96.5 \text{ Geogr. miles}.$$

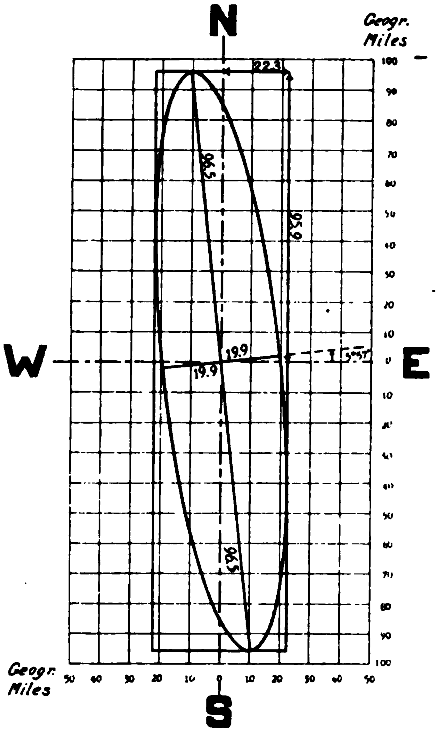


Fig. 4.

The ellipse is seen to be very elongated in the direction of latitude and any further stations which would be brought into the calculations should be chosen along the N-S axis, so as to diminish the eccentricity of the figure and thereby greatly increase the reliability of the results.

TABLE I.

Δ	T	d	Δ	T	d	Δ	T	d	Δ	T	d
0°	0s	15s	30°	388s	10s	60°	611s	7s	90°	795s	6s
1	15	16	31	398	9	61	618	6	91	801	5
2	31	16	32	407	9	62	624	7	92	806	6
3	47	15	33	416	9	63	631	6	93	812	5
4	62	15	34	425	8	64	637	7	94	817	6
5	77	15	35	433	9	65	644	6	95	823	5
6	92	15	36	442	8	66	650	6	96	828	6
7	107	14	37	450	8	67	656	7	97	834	5
8	121	15	38	458	8	68	663	6	98	839	5
9	136	14	39	466	8	69	669	6	99	844	5
10	150	14	40	474	8	70	675	7	100	849	6
11	164	14	41	482	7	71	682	6	101	855	5
12	178	14	42	489	8	72	688	6	102	860	5
13	192	14	43	497	7	73	694	7	103	865	5
14	206	13	44	504	7	74	701	6	104	870	4
15	219	13	45	511	7	75	707	6	105	874	5
16	232	12	46	518	7	76	713	6	106	879	5
17	244	13	47	525	7	77	719	6	107	884	4
18	257	12	48	532	7	78	725	6	108	888	5
19	269	12	49	539	7	79	731	6	109	893	5
20	281	12	50	546	6	80	737	6	110	898	5
21	293	11	51	552	7	81	743	6	111	903	4
22	304	11	52	559	6	82	749	6	112	907	5
23	315	11	53	565	7	83	755	5	113	912	4
24	326	11	54	572	6	84	760	6	114	916	4
25	337	11	55	578	7	85	766	6	115	920	5
26	348	10	56	585	6	86	772	6	116	925	4
27	358	10	57	591	7	87	778	5	117	929	4
28	368	10	58	598	6	88	683	6	118	933	5
29	378	10	59	604	5	89	789	6	119	938	4
30	388		60	611		90	795		120	942	

TABLE II.

STATION 1, SAINT LOUIS UNIVERSITY.

	$^*\lambda_0$, $^*\varphi_0$.	($^*\lambda_0+\partial^*\lambda_0$), $^*\varphi_0$.	$^*\lambda_0$, ($\varphi_0+\partial^*\varphi_0$)
Epicentric Latitude, φ_0	19° 00' 00"	19° 00' 00"	20° 00' 00"
Station Latitude, φ_1	38 38 15	38 38 15	38 38 15
Epicentric Longitude, λ_0	103 00 00	104 00 00	103 00 00
Station Longitude, λ_1	90 13 58.5	90 13 58.5	90 13 58.5
$\lambda_0 - \lambda_1$	12 46 2	13 46 2	12 46 2
Log. cos.($\lambda_0-\lambda_1$)	9.9891	9.9873	9.9891
Log. cos φ_0	9.9757	9.9757	9.9729
Log. cos φ_1	9.8927	9.8927	9.8927
Log. II	29.8575	29.8557	29.8575
Log. sin φ_0	9.5126	9.5126	9.5340
Log. sin φ_1	9.7954	9.7954	9.7954
Log. I	19.3080	19.3080	19.3294
II	.7203	.7173	.7157
I	.2033	.2033	.2135
Cos.$^*\Delta_1$	.9236	.9206	.9292
$^*\Delta_1$	22° 32'	$^*\Delta_{1_\lambda}$ = 22° 59'	$^*\Delta_{1_\varphi}$ = 21° 41'
$(\partial^*\Delta_1+\partial^*\lambda_0)\cdot\delta^*\lambda_0$	−7'.76	$^*\Delta_1$ = 22° 32'	$^*\Delta_1$ = 22° 32'
$(\partial^*\Delta_1+\partial^*\varphi_0)\cdot\delta^*\varphi_0$	+39'.00	$\partial^*\Delta_{1_\lambda}$ = 27'	$\partial^*\Delta_{1_\varphi}$ = −51'
Δ_1	23° 3'.24		
		$\dfrac{\partial^*\Delta_1}{\partial^*\lambda_0}$ = +.45	$\dfrac{\partial^*\Delta_1}{\partial^*\varphi_0}$ = −.85
$^*T_1$	0° 5' 10"	a_1 = .081	
$^*t_0$	11h 2m 32s	b_1 =−.153	
$^*t_1 = {}^*T_1 + {}^*t_0$	11h 7m 42s	c_1 = 1	
$^*\gamma_1 = t_1\dagger - {}^*t_1$	4s	s_1 = .928	
t^s_1 + 60 =.18			

TABLE III.

n	a	b	c	s	γ
1	+.08	−.15	+1	+.93	+4
2	+.02	−.15	+1	+.87	-3
3	+.09	−.11	+1	+.98	-1
4	+.09	−.12	+1	+.97	-3
5	−.11	−.14	+1	+.76	+5
6	+.07	−.11	+1	+.96	0

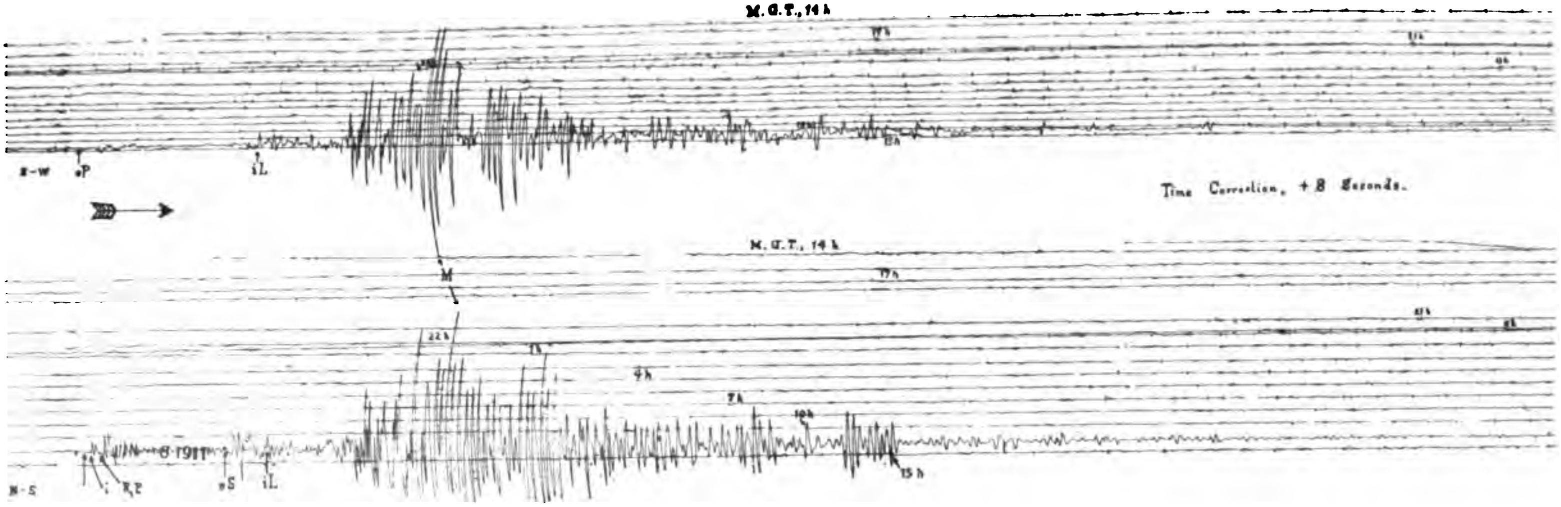
TABLE V.

	St.Louis	St.Boniface	Harvard	Buffalo	Santa Clara	Ottawa
a_n	+.08	+.02	+.09	+.09	−.11	+.07
b_n	−.15	−.15	−.11	−.12	−.14	−.11
$a_n\cdot\delta\lambda_0$	−1.7	−.4	−1.9	−1.9	+2.3	−1.5
$b_n\cdot\delta\varphi_0$	+4.6	+4.6	+3.4	+3.7	+4.3	+3.4
δt_0	−2.8	−2.8	−2.8	−2.8	−2.8	−2.8
$-\gamma$	−4.	+3.	+1.	+3.	−5.	0.
ℓ_n	−3.9	+4.5	−.3	+2.	−1.2	−.9

TABLE IV.

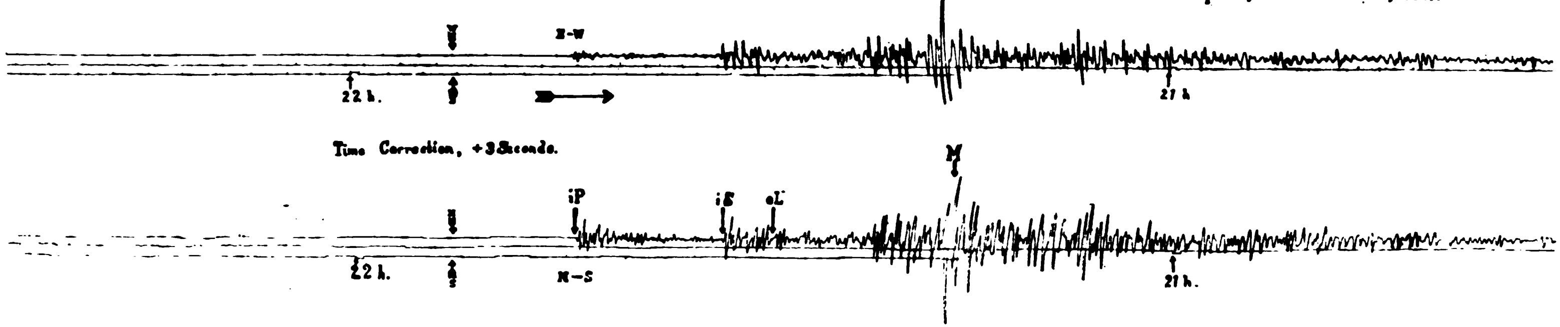
$aa=$ .04	$ab=$ −.0280 $bb=$ +.1032 $\frac{ab}{aa}ab=$ +.0196	ac +.2400 $bc=$ −.7800 $\frac{ab}{aa}ac=$ −.1680	$aS=$ +.2509 $bS=$ −.7062 $\frac{ab}{aa}aS=$ −.1756	$aF=$ −.6500 $bF=$ −.3800 $\frac{ab}{aa}aF=$ +.4550	TABLE IV.	
$\frac{ab}{aa}=$ −.7000 $\frac{ac}{aa}=$ +6.0000 $\frac{aF}{aa}=$ −16.2500 $\frac{1}{D}=$ +3742.7200	$bb_1=$ +.0836 $\frac{bc_1}{bb_1}=$ −7.3205 $\frac{bF_1}{bb_1}=$ −9.9880 $\frac{cF_2}{cc_2}=$ −2.6608 $\mu=$ ±3.6755	$bc_1=$ −.6120 $cc=$ +6.0000 $\frac{ac}{aa}ac=$ +1.4400 $cc_1=$ +4.5600 $\frac{bc_1}{bb_1}bc_1=$ +4.4801 $cc_2=$ .0799	$bS_1=$ −.5306 $cS=$ +5.4700 $\frac{ac}{aa}aS=$ +1.5054 $cS_1=$ +3.9646 $\frac{bc_1}{bb_1}bS_1=$ +3.8843 $cS_2=$ .0803	$bF_1=$ −.8350 $cF=$ +2.0000 $\frac{ac}{aa}aF=$ −3.9000 $cF_1=$ +5.9000 $\frac{bc_1}{bb_1}bF_1=$ +6.1128 $cF_2=$ −.2126	$FS=$ +1.0200 $\frac{aF}{aa}\cdot aS=$ −4.0771 $FS_1=$ +5.0971 $\frac{bF_1}{bb_1}bS_1=$ +5.2996 $FS_2=$ −.2025	$FF=$ +60.0000 $\frac{aF}{aa}\cdot aF=$ +10.0000 $\frac{bF_1}{bb_1}bF_1=$ +8.3400
$bb\cdot cc=$ +.6192 $bc\cdot bc=$ +.6084	$aa\cdot cc=$ +.2400 $ac\cdot ac=$ +.0576	$aa\cdot bb=$ +.004128 $ab\cdot ab=$ +.000784	$ab\cdot cc=$ −.1680 $ac\cdot bc=$ −.1872	$ac\cdot bb=$ +.024792 $ab\cdot bc=$ +.021840	$bc\cdot aa=$ −.031200 $ab\cdot ac=$ −.006720	$\frac{cF_2}{cc_2}cF_2=$ +.5657
$Z_{\lambda\lambda}=$ +.0108 $Q_{\lambda\lambda}=$ +40.4214 $\sqrt{Q_{\lambda\lambda}}=$ ±6.3586 $\mu_\lambda=$ ±23'.37	$Z_{\varphi\varphi}=$ +.1824 $Q_{\varphi\varphi}=$ +682.6721 $\sqrt{Q_{\varphi\varphi}}=$ ±26.1279 $\mu_\varphi=$ ±96'.13	$Z_{tt}=$ +.003344 $Q_{tt}=$ +12.5157 $\sqrt{Q_{tt}}=$ ±3.5377 $\mu_t=$ ±13s	$-Z_{\lambda\varphi}=$ −.0192 $Q_{\lambda\varphi}=$ −71.8602 $Q_{\lambda\lambda}=$ +40.4214 $Q_{\lambda\varphi}=$ −71.8602 $Q_{\lambda t}=$ −11.0485	$-Z_{\lambda t}=$ −.002952 $Q_{\lambda t}=$ −11.048500 $Q_{\lambda\varphi}=$ −71.860200 $Q_{\varphi\varphi}=$ +682.672100 $Q_{\varphi t}=$ +91.621800	$-Z_{\varphi t}=$ +.024480 $Q_{\varphi t}$ +91.621800 $Q_{\lambda t}=$ −11.048500 $Q_{\varphi t}=$ +91.621800 $Q_{tt}=$ +12.515700	$ff=$ +40.5300 $\delta\lambda_0=$ −20'.9 $\delta\varphi_0=$ −29'.5 $\delta t_0=$ −2.7sec
			$Q_\lambda=$ −42.4873 $aS\cdot Q_\lambda=$ −10.6601	$Q_\varphi=$ +702.433700 $bS\cdot Q_\varphi=$ −496.0587	$Q_t=$ +93.0890 $aS\cdot Q_t=$ +509.1968	$\lambda_0=$ 102°39'±23' $\varphi_0=$ 18°30'±96' $t_0=$ 11h 2m 29s ± 13s

Mexican Earthquake, June 7, 1911.



Time Correction, + 8 Seconds.

Mexican Earthquake, December 16, 1911.



Time Correction, + 3 Seconds.

Jesuit Seismological Service Record of the Earthquake Station, St. Louis University.

ST. LOUIS, MO., U. S. A.

LATITUDE: 38° 38′ 17″ N.
LONGITUDE: 90° 13′ 58″.5 or 6^h. 0^m. 55^s.9 W. Gr.
ALTITUDE: 160.36 m.

TIME: Mean Greenwich, midnight to midnight.
INSTRUMENT: Wiechert 80 kg., astatic, horizontal pendulum.

NOMENCLATURE: International.

The symbols used in the following records are those of the *International* Nomenclature, which is identical with that given by us in the December Bulletin of the University (1911). For the sake of those who may wish to make further use of our data, we preface the records with the list of constants for the year.

Date.	*E*			*N*		
	T	*V*	ϵ	*T*	*V*	ϵ
	s			*s*		
Jan. 3..	7.	85	5.	7.	97	5.4
Jan. 7..	7.	85	5.1	7.	79	5.1
Jan. 21..	6.9	89	5.4	6.3	98	5.
Feb. 17..	7.	94	5.	7.	98	4.9
Feb. 21..	7.	82	5.	7.	86	5.
May 1..	6.7	91	4.1	7.	89	5.7
June 6..	7.	67	5.	7.	79	5.
Aug. 17..	7.	..	...	7.	..	...
Sept. 17..	6.5	85	5.	7.	90	5.
Sept. 22..	7.	93	5.6	7.	83	6.2
Oct. 10..	7.	79	5.	7.	86	5.
Nov. 21..	7.	88	...	6.5	84	...
Dec. 17..	6.8	88	5.	7.	83	6.

EARTHQUAKE RECORDS FOR 1911.

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS
			h m s	s	A_E μ	A_N μ	
Jan. 3–4	III_u	S_E	23 50				P, if present on either component, cannot be recognized on account of microseismic disturbances. The waves in S and first part of L are too irregular for accurate determination of amplitude or period; the earth motion was apparently very complicated. A short train of large irregular waves appeared on N-S component at 23h 57m .7 between time for RS_1 and RS_2; cannot identify them. Turkestan.
		S_N	23 50.6				
		L_E	0 12				
		L_N	0 13.4				
		M_E	0 16	34	847		
		M_N	0 27.9	21		488	
		F_E	2				
		F_N	2				
Feb. 4	I	eL_N	4 29.7				
		M_N	5 06.5	30		6	E-W component shows no distinct M.
		eL_E	5 38.6				
		F_E	7 24.1				
Feb. 4	I	eL_N	8 51.6				
		M_N	9 07.8	12		1	No decided M on E-W.
		eL_E	9 22.6				
		F_N	9 46.6				
		F_E	9.48.6				
Feb. 5	Ir	iP_N	4 29.4	3		5	No trace on P on E-W component.
		I_N	4 29.6	3.9		4	The train of waves at 4; 31.5 seems to be PS.
		RP_N	4 29.7				Distance calculated 2690 km.
		PS?	4 31.5				Co-ordinates of the epicenter, as determined from data supplied by Ottawa, Harvard, St. Boniface and St. Louis, were λ=89°, φ=14°23', near San Salvador, Central America.
		iS_N	4 33.7	4		6	
		eS_E	4 33.7				
		I_E	4 34.1				
		I_N	4 34.6	6		6	
		eL_E	4 35				
		M_N	4 39.7	6		9	

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS
			h m s	s	A_E μ	A_N μ	
Feb.5		M_E	4 39.7	5.1	13		
		C_E	4 42.7				
		F_N	4 51.2				
		F_E	4 54				
Feb.17	I	eP_E	14 28.8				
		eP_N	14 29.8				
		eS_E	14 32.8				
		L	14 33.8				
		M_E	14 34.9	6	12		
		M_N	14 35.6	7.8		18	
		F	15 01				
Feb.18	I	eL_N	2 03				
		eL_E	2 04.5				
		M	2 06.4	9.6	14	16	
		F_E	2 16				
		F_N	2 20				
Feb.18	IIu	e_E	19 22.1				Up to 19^h 43^m the motion on both components was very complicated and irregular. Central Asia.
		e_N	19 25.6				
		S_E	19 27.4				
		L_E	19 34.1				
		eL_N	19 36.1				
		M_E	19 38.6	18	102		
		M_N	19 45.1	18		211	
		F	20 10				
Feb.28	I	eL_E	4 24.6				
		F	6 00.6				

DATE	CHARACTER	PHASE	TIME			PERIOD T	AMPLITUDE		REMARKS
			h	m	s	s	A_E μ	A_N μ	
Mar. 10	I	eL_N	1	28					
		M_N	1	34.7		17		6	
		F_N	3	18					
Mar. 10	I	eL_E	11	2.7					
		F_E	11	45					
Mar. 22	I	eL_N	7	02					
		F_N	8	37					
Apr. 10	Ir	P	18	49.2					Distance 3660 km. According to reports received from northern Columbia by the Jesuit Observatory of Havana, the epicenter of the earthquake was between Bogota and Cartagena. The macroseismic data furnished by Havana, Ottawa, Trieste and Saint Louis, place the epicenter at: Long. 75° 50' W., Lat. 8° 36' N.
		S_E		54.6		7	8		
		S_N		54.6		9		11	
		L		57.2					
		M_E	19	3.5		14	22		
		M_N		4.2		15		34	
		F		23					
Apr. 28	IIr	P	10	0.4					
		L_N		7					
		L_E		7.1					
		M_E		7.2		6	13		
		M_N		7.2		5.5		15	
		F_E		22					
		F_N		51					

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS
			h m s	s	A_E μ	A_N μ	
May 4–5	IIu	P	23 48.1				
		iS_N	57.5	6		25	$(S-P)_N$ = 9m31s Distance 8200 km.
		iS_E	58.1	6	8		$(S-P)_E$ = 10m6s Distance 8900 km.
		L	0 10.6				The co-ordinates calculated from
		M_E	11.6	24	105		data furnished by Darmstadt, Vi-
		M_N	12.2	21		95	enna and Saint Louis, are:
		F_E	14				Long. 152° 30'E
		F_N	19				Lat. 51° N.
							Kamtchatka.
Jun. 7	IIIr	eP_N	11 07.7+				$(S-P)_N = 4^m\ 13^s$
		eP_E	07.8	T_e			Δ= 2600 km.
		iP	07.9	7.4	8	68	Mexico
		R_1P	08.2	T_n 8.3			
		iS	11.9				
		iL	13.2				
		M_{1N}	17.4	15		1580	
		M	18	12	1306	1265	
		F	13 35				
Jun. 15	II	i_{1E}	14 47.1	7.8	75		Phases are doubtful owing to
		i_{1N}	47.1	8.4		90	interference of two quakes.
		i_2	53.3	6	42	36	China Sea and Mexico
		F	15 33				
Jul. 1	Ir	eP_E	22 9.9				Epicenter near San Francisco.
		L	16.5				
		M	16.6	10.8	55	60	
		F_E	47.1				
		F_N	55.5				

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS
			h m s	s	A_E μ	A_N μ	
Jul. 4	I	e_N	13 56.2				Turkestan.
		e_E	56.3				
		F_E	14 42.4				
		F_N	47.2				
Jul. 12	I	i_s	4 28.3				Japan.
		i_{sE}	38.1				
		i_{sN}	38.2	12	77		
		F_N	5 54.6				
		F_E	5 54.8				
Aug. 16	Iu	eP	22 57 42				Guam.
		S	23 10 12				
		L	33 36				
		M_E	0 01 09	19	90		M_N indistinct.
		F	1 11 00				
Aug. 21	I	i	16 52 12				Near Kamtchatka?
		F	17 10 00				
Aug. 27	I	e	11 02 50				P and S too doubtful for determination. Mexico
		eL	08 08				
		F	37 00				
Sep. 15	Iu	P	13 28 35				$(S-P) = 7^m\ 10^s$ Distance 5550 km.
		S	35 45				
		eL_E	41 18				
		eL_N	42 18				
		M_N	45 08	27		81	
		M_E	47 38	18	32		
		F	15 30				
Sep. 17	Iu	iP	3 40 23				$(S-P)_N = 8^m\ 30^s$ Distance 7000 km. Chili.
		S_N	48 53				

DATE	CHARACTER	PHASE	TIME			PERIOD T	AMPLITUDE		REMARKS
			h	m	s	S	A_E μ	A_N μ	
		S_E	3	49	11				
		eL_N		59	23				
		eL_E	4	00	53				
		M_E		01	17	15	49		
		M_N		06	20	17		78	
		F		42					
Sep.22	Iu	eP_N	5	15	29				(S-P) = 7^m
		eP_E		15	35				Distance 5300 km. Alaska.
		eS_N		22	29				
		eS_E		22	35				
		L_N		27	59				
		L_E		28	53				
		M_N		29.	08	8		1mm	
		M_E		29	09	9	1mm		
		F		53					
Oct.6	IIr	iP	10	21	53				$(S-P)_E$ = 4^m 42^s.
		iS_N		26	33				Distance 3000 km. Haiti
		iS_E		26	35				
		L_N		29	39				
		L_E		29	44				
		M_N		31	30	15		204	
		M_E		5.1	30	15	172		
		F	14	14					
Oct. 10	Ir	iP	13	18	03				Same determination as for
		iS		22	45				October 6.
		L_N		25	33				
		L_E		26	00				
		M_N		35	00	12		30	
		M_E		35	45	12	25		
		F	14	00					

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS.
			h m s	s	A_E μ	A_N μ	
Oct. 15	I	e	16 58?				S and P could not be determined on account of microseismic disturbances.
		L_E	39				
		L_N	11.9				
		M_E	12.5	15	25		
		F	18 02				
Oct. 29	Ir	P_N	18 20.9				
		P_E	21				
		S_E	25.9				
		S_N	26				No distinct Maximums.
		L_E	28.1				
		L_N	28.9				
		F	46				
Nov. 18	I	P_N	7 38.2				P_E and S_E not distinct.
		S_N	43				
		L_N	48				
		F	8 06				
Nov. 20	I	P_N	13 54.7				Distance 3150 km.
		P_E	55.5				
		S_N	58.5				
		L_N	14 05				
		L_E	06.5				
		M_E	08	15	18		
		M_N	08.5	15		44	
		F	16.5				
Nov. 22	I	e	10 20.4				E-W too indistinct.
		L_N	21				
		F	27.3				
Nov. 25		P_E	19 35.8?				
		P_N	37 ?				
		S_E	39.8				
		S_N	42				
		L_E	42.8				
		L_N	43				
		M_N	43.6	12		35	
		M_E	45	12	15		P lost in microseisms.

DATE	CHARACTER	PHASE	TIME		PERIOD T	AMPLITUDE		REMARKS.
			h	m s	s	A_E μ	A_N μ	
Dec. 16	IIIr	iP_E	19	19.4	638	12		
		iP_N		19.5	638		23	$(S-P)_N=4^m\ 20^s$.
		iS_E		23.8	8.7	3		Distance 2690 km. Mexico.
		iS_N		23.8	8.7		49	
		L_E		25.2				
		L_N		25.3	145			
		M_N	19	30			1064	
		M_E		30	12	546		
		F_N	21	06.5				
		F_E		12.5				
Dec. 22	I	P	13	00.1				
		S_E		04.6				$(S-P)_N = 4^m\ 30^s$ Distance 2830 km.
		S_N		04.6				
		L_N		08.1				
		L_E		08.2				
		M_N		20.6	13		45	
		M_E		20.7	13	34		
		F		38				
Dec. 23	I	e	7	57.9				
		L_N		58.8				
		L_E		58.7				P overlapped by following quake
Dec. 23	I	e_N	8	08.6				
		e_E		07.5				
		F		43				

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AUSTRIA.

Cracow.—K. k. Sternwarte.—*Wöch. Erdb.*, Nos. 1-46, 1911.

Graz.—Physik. Institut, Dr. A. Fritsch.—*Wöch. Erdb.*, No. 1-16. Dr. Norbert Stücker.—*Wöch. Erdb.*, Nos. 17-52, 1911. Dr. N. Stücker u. Dr. A. Fritsch.—*Seismische Registrierungen in Graz. Dritter Bericht für das Jahr* 1909. Dr. N. Stücker.—*Seismische Registrierungen in Graz, Vierter Bericht für das Jahr* 1910.

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Symons' Monthly Meteorological Magazine, 27 Volumes.
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An Appeal.

THE NEEDS OF OUR GEOPHYSICAL OBSERVATORY.

For some time past the authorities of the Observatory have been contemplating the purchase of a reliable astronomical normal clock, which would give the exact time for the other clocks necessary to the Observatory; but up to the present we have been unable to do so for lack of funds. The want of such a timepiece is seriously felt in all departments, and until it is supplied the scientific work of the observatory will be greatly handicapped.

Another pressing need is that of the completion of our seismological equipment. Only one instrument of the required set has so far been installed, and as a result the better of our two vaults, which rests on the solid rock of nature, 18 feet below the surface of the ground, is lying idle, awaiting some generous donor who will supply the missing vertical and more sensitive horizontal seismographs which have been planned for it.

Then, too, the umbrella aerial, mentioned in connection with the ceraunophone, for the determination of the direction of distant thunderstorms; apparatus for the quantitative registration of atmospheric and telluric electricity and magnetism; also geophysical apparatus for our laboratory, would be of the greatest service in the study of the problems the Observatory has now in hand.

It is due to the generosity of friends that the Observatory is in existence, and, as it has no reserve fund or endowment of any kind, their continued generosity is its greatest necessity. Hence it is with no little hesitation that we put these additional wants before them, but we are confident that there are others interested in scientific work who would be able and willing to assist us if our needs were only suggested to them.

John B. Goesse, S. J.,
Director.

George E. Rueppel, S. J.,
Assistant.

St. Louis University

—1818—

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The
Geophysical Observatory

Meteorological and Seismological Departments

UNDER THE DIRECTION OF

JOHN B. GOESSE, S. J.,
AND
GEORGE E. RUEPPEL, S. J.

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PART I.

Meteorology

Meteorology in St. Louis University.

SCOPE OF THE WORK.

The propriety of establishing a Meteorological Observatory as a department of a University may not be so obvious as to require no word of justification. If our universities seek to promote the material welfare of the world by subsidizing and operating laboratories for research in agriculture, electricity, biology, medicine and a score of other sciences, why not, on the same plea, assume a like attitude toward the study of the weather? True, other sciences enable us to get in more direct contact with the forces of nature and to make them the servants of our necessities and pleasures, while the meteorologist, after all his probing into the laws governing the phenomena of our atmosphere, may be able to do little more than foresee weather conditions at a comfortable distance, without being able to offer further protection. Thus stated, the advantages offered may not seem worth the effort; but they assume tremendous proportions when measured in terms of property saved, health and lives preserved. If such be the nature and extent of the advantage to be gained, there should be no hesitation in giving meteorology its proper relation to the other sciences now fostered in our universities.

This position gains strength from the fact that meteorologists themselves, at least in this country, look to the universities for assistance in solving their larger problems. At the Peoria Convention of Weather Bureau Officials, Professor Cleveland Abbe said: "We have also to wish that the professors and special mathematical students interested in meteorology shall have their attention directed specifically to some of our problems; for instance, the mathematical expressions for the action of the wind on a plane surface. . . . But there are still grander problems for the mathematicians of the universities. I refer to the motions of the atmosphere and the attendant temperature and rainfall."

Some experts, such as Professor Langley, have been lending their assistance in this way. The truest response to Professor Abbe's suggestion, however, assumes the shape of liberal endowments, for the purpose of putting the work on a safe and independent footing. A gift of this sort has furnished this observatory with its preliminary equipment, and it is only with the help of similar gifts that the research work, for which it was principally established, can be carried on.

In recent years the teaching of meteorology has been taken up, in one way or another, by a very large number of High Schools, Colleges and Universities, and in some places even by the Primary Schools. The extent to which it is adopted and the methods employed differ so widely, however, that it may be well to state here what attitude St. Louis University has assumed.

The proper time to introduce the youth of this country to the elements of meteorology is evidently the High School period. In the three High Schools of St. Louis University elementary meteorology is an elective, with Tarr as a text book. In the College of Arts and Sciences and in the School of Philosophy and Science, meteorology is taught only indirectly, the respective professors of the various courses in physics being permitted to use their own judgment as to the extent to which the application to this science of the principles of mechanics, heat, molecular physics, electricity and magnetism should be enlarged upon. This conservative attitude is dictated chiefly by a familiar circumstance, local as well as general. The average student interested in science is bent on investing the capital of his talents in projects that give promise of big dividends. From this point of view, meteorology as a profession offers no strong temptation. For the Weather Bureau service—by which alone at present, in the absence of endowed positions at our universities, any inducements are offered—admittedly does not bear comparison in point of remuneration with other occupations open to the prospective engineer or physicist.

The alternative, suggested by Professor Abbe on the occasion mentioned above as a means of making the most of this very actual condition, viz., to induce our students to take up some special meteorological problems as a side issue, is put into practice at St. Louis University in the following manner:

This observatory has a definite number of assistant positions which are open to capable applicants. Whilst incumbents are expected to do the routine work, and to be at the general disposal of the officials in charge, they are supplied with all books and equipment necessary to obtain a thorough knowledge of the principles of the science, are permitted to do observational work, and are given individual direction in their efforts. They are kept in close touch with recent developments, especially with the research work at the observatory. No fee is demanded. At present eight students, mostly interns, are availing themselves of these opportunities to a greater or less extent. This same method is followed in the Department of Seismology, and it may be mentioned here that the majority of the assistants lend their help in both departments.

Whatever greater good may come of this method, this much is assured, that a large number of capable minds will have become sufficiently interested and experienced in the science to contribute, to the extent of their opportunities, some of the "bricks and mortar" of which the much desired result will eventually be built up.

This observatory heartily seconds the efforts made by the U. S. Weather Bureau officials to familiarize the general public with the main working principles of meteorology, and thereby to eradicate old superstitions and prejudices.

LOCATION OF OBSERVATORY.

Latitude: 38° 38′ 17″ north.

Longitude: 90° 13′ 58″.5 west.

Elevation: 578 ft. above sea level.

Wind Vane: 94 ft. above ground.

Anemometer: 96 ft. above ground.

Top of Rain Gauge: 80 ft. above ground.

Floor of Thermometer Shelter: 10 ft. above roof and 86 ft. above ground.

Explanation to Meteorological Summaries.

Atmospheric Pressure in inches reduced to mean sea level.

Mean Temperature: the mean of three daily observations.

Mean Vapor Pressure and Mean Relative Humidity: the mean of the three daily readings of the various thermometers reduced according to the method used by the U. S. Weather Bureau.

Signs used for Miscellaneous Phenomena: The International Meteorological Symbols.

The official day ends with 7:00 P. M., except for wind velocity and direction, which end at 12:00 midnight.

Equipment.

The present equipment of the observatory consists of the following instruments:

1.) Fortin Barometer.
2.) Barograph, Richard Bros. pattern.
3.) Thermograph, Richard Bros. pattern.
4.) Maximum and Minimum Thermometers.
5.) Whirling Psychrometer.
6.) Hygrograph.
7.) Thermograph.
8.) Tipping Bucket Rain Gauge.
9.) Snow Gauge.
10.) Electrical Sunshine Recorder.
11.) Jordan's Photographic Sunshine Recorder.
12.) Wind Vane.
13.) Anemometer (Robinson).
14.) Meteorograph (Quadruple Register).
15.) Ceraunograph (Lightning Recorder).
16.) Ceraunophone.
17.) Thermostatic and Temperature Alarm.
18.) Ground Thermometers.
19.) Several Standard Thermometers.
20.) Electograph.

The instruments are of standard make and of United States Weather Bureau patterns.

THE WEATHER OF 1912.

For the first 13 days of the year the minimum temperature averaged lower than for any recorded period of similar duration. For those thirteen days the average minimum temperature was 1.8°, while the mean temperature for the same period was 9° above zero. For 16 consecutive days the mercury remained below the freezing point. The lowest temperature reached during the month was —16°, and the highest 57°. On the 21st the thermometer rose 32 degrees, the greatest range of temperature for any single day. The total snowfall of 19 inches was unusually heavy, while the ground temperature (five feet below the surface) reached its absolute minimum since observations were first taken; a remarkable fall of 7° in the month indicated how deeply the cold had penetrated the ground. The long continued low temperature of the first sixteen days made this month the coldest January in more than half a century. As a result, the Mississippi River was frozen over by the 9th and was in that condition at the end of the month.

February, 1912.

The excessive weather conditions of the preceding month continued into February, making it one of the most severe on record. The thermometer ranged from 60° to —9°, while the mean temperature for the month stood at 29°, or 5° below the normal, and 11° below the mean of the same month in the preceding year. The precipitation for the month was likewise far in excess of the normal; the total amount of unmelted snow was 34 inches, or twice as great as that recorded for February, 1911. On the 20th and 21st a record snowstorm occurred, when the gauge showed 25 inches in the 24 hour period. Of the 29 days only 7 showed a perfect sunshine record, while the average daily sunshine was 41%. During the month six solar halos were observed. A gale of 48 miles an hour on the 21st marked the maximum wind velocity for the month.

March, 1912.

The abnormal conditions of the year were continued during this month, which has the distinction of being the snowiest and rainiest March during 75 years. There were 8 clear days, an average daily sunshine of 40% and a mean temperature of 36°. This, with the single exception of March, 1906, with a mean temperature of 34°, was likewise the coldest March since 1843. Precipitation occurred on 18 days, a total of 5.43 inches, 2 inches above the normal. A remarkable feature was a succession of severe snowstorms. On the 16th an agreeable change to mild and balmy weather gave promise of Spring. On Sunday, the 17th, about 50,000 people visited the parks, and the severe Winter seemed to be over at last. But on the following Sunday, the 24th, all promises of Spring were broken by another extraordinary weather freak of this abnormal year. This was a record-breaking snowfall of 15 inches in about 10 hours. This unseasonable blizzard crippled the car service and rendered the roads unpassable to automobiles. The melting of the snow at the end of the month brought with it damaging floods on the lower Mississippi, accompanied by loss of life and property. Cold and moisture in the soil hampered farming operations, and all crops were unusually backward.

April, 1912.

April was ushered in by moderately high temperatures, causing a decided improvement in weather conditions. The total precipitation for the month, 7.66, was again above the normal, and only twice exceeded in April since 1831. A torrential rain on the 14th was accompanied by hail, and pedestrians were forced to cross street corners in six inches of water. Another severe rain on the 25th, accompanied by a high wind, which reached a maximum of 70 miles an hour, caused considerable damage in and around St. Louis. Trees were uprooted, houses unroofed, and plate-glass windows were shattered. During 12 hours the precipitation totalled 2.50 inches. Cyclones and tornadoes south of Missouri gave evidence of the wide area of this disturbance. There were 14 clear days and 56% average daily sunshine.

May, 1912.

A few meteorological eccentricities were displayed by May, otherwise the month's weather was normal. The mercury reached its highest, 89°, on the 23d, and the lowest, 44°, on the 18th, while the mean temperature was 3° above the normal. There were 19 clear days and 70% of sunshine; six consecutive days were without a trace of clouds. Precipitation was slightly above normal, more than half of the total amount was confined to 2 days; while on the 28th 1.64 inches of rain fell in six hours, fully half of it within five minutes. Moderate temperatures marked the first week; cool weather the second, and excessive dryness the third; while the fourth and last week saw the temperature well above the normal.

June, 1912.

The most remarkable feature of this month was the heavy rain, the fourth heaviest for June in 75 years. Almost 9 inches were recorded, as against 1.79 for June, 1911. On June 16th the total precipitation reached 3.98 inches within 24 hours; 3.07 inches within one hour and twenty minutes. The analyzed record follows:

5 min.	0.14 in.	25 min.	1.18 in.	45 min.	2.28 in.
10 min.	0.41 in.	30 min.	1.30 in.	50 min.	2.50 in.
15 min.	0.72 in.	35 min.	1.58 in.	60 min.	2.95 in.
20 min.	0.99 in.	40 min.	1.98 in.	80 min.	3.07 in.

This downpour was accompanied by heavy thunderstorms; more than 100 buildings were struck by lightning. The Mississippi rose more than 3 feet in 24 hours. Basements all over the city were flooded, sewers were blown up and much damage was done, especially to the new Kingshighway Viaduct, sixty feet of which was washed away, the loss amounting to more than $10,000. The mean temperature for the month was 5° below the normal, and ranged between 51° on the 8th and 89° on the 26th. The month showed 12 clear days, and an average daily sunshine of 61%.

July, 1912.

With the month of July the year approached for the first time to normal weather conditions. The temperature ranged from 64° on the 16th and 19th to 96° on the 24th. This range was somewhat less than that recorded for 1911, which had shown a minimum of 56° and a maximum of 101°. The contrast in precipitation between these same months was, however, very marked. July, 1912, recorded 6.22 in. The corresponding month in 1911 had totalled but 0.74 in. A phenomenal downpour occurred on the 14th, when 3.17 were registered within the space of two hours. Of this quantity 1.97 in. fell in twenty-five minutes and 2.91 in. in one hour, the greatest amount ever recorded in one hour in St. Louis. The prevailing wind was from the South, and recorded a total for the month of 5003 miles. The greatest velocity was reached on the 10th, when the anemometer recorded 60 miles an hour from the Northwest. This high wind, accompanied with rain and electrical disturbances, did much damage in the city and terrified those who habitually see in every unusual storm a repetition of the cyclone of 1896. A drop of 16° in temperature within 10 minutes was one of the features of this storm; another was the highly localized nature of the precipitation. While more than an inch of rain fell in the West End and 0.56 in the downtown districts, the southern portion of the city was almost dry. The ground temperature showed an increase of 6° and reached the annual maximum. Of 11 thunderstorms during the month one was attended by hail. The sunshine record showed 15 clear, 9 partly cloudy and 7 cloudy days, while the mean relative humidity of 70° was unusually high for this season of the year.

August, 1912.

While the mean temperature for August was about normal, the first week of the month exhibited a continued persistence of low temperature. The fourth recorded the lowest minimum for that day since 1842, and the morning of the 5th was the coolest ever recorded for early August. The second week marked a slow return to seasonable temperature, although the average remained subnormal, and on only one day during the first half of the month did the mercury reach 90°. During the latter half of this month conditions were restored to normal, and the maximum, 96°, was reached on the 28th. The total precipitation, 2.68 in., was the lowest for any month since January, and 0.46 was the greatest amount recorded for any 24 hour period. The prevailing wind shifted to the West, with a mileage of 4945, while the highest velocity was reached on the 25th, when a current from the Southeast reached 42 miles an hour. The sunshine record of 235 hours gave a daily average of 60%, with 14 clear, 8 partly cloudy and 9 cloudy days. Twelve thunderstorms passed over St. Louis during the month.

September, 1912.

The hot weather of later August continued unabated well into the first half of September, reaching its culmination on the 6th with a maximum of 97°, the highest in the year. On the 12th the long awaited relief occurred, and a marked contrast is shown by the exceptionally cool weather which continued throughout the remainder of the month. The minimum, 43°, on the 26th, is the lowest ever recorded for that day. While the mean temperature for the month was 4° lower than that of the same period of 1911, it was slightly higher than the normal. Practically no rain fell in St. Louis during the first half of the month, but some heavy downpours occurred during the latter portion. Thus, on the 17th, one inch fell in 12 hours, and on the 20th and 21st 1.30 in. fell in 20 hours. The total for the month, however, was but 2.61, fully 4.50 in. less than that recorded for September, 1911. The sunshine record shows 19 clear days and an average for the month of 68%. Fog and thunderstorms occurred on 6 and 5 days, respectively. The prevailing winds from the Southeast reached a total of 4257, with a maximum velocity on the 20th of 42 miles.

October, 1912.

October showed no unusual weather conditions. The mean temperature of 62°, 4° above normal, ranged from 86° on the 6th to 36° on the 23d, when the first light frost of the season was recorded. Fifteen clear, 8 cloudy and 8 partly cloudy days gave 66% of sunshine. Five thunderstorms furnished 2.46 in. of rain, a trifle above normal. On the last day of the month occurred the heaviest precipitation, 1.46 in. during 13 hours. The prevailing wind from the Southeast reached a total mileage of 5295, an average hourly velocity of 7 miles.

November, 1912.

During November an ideal "Indian Summer" prevailed, with an average daily sunshine of 62% and 14 clear days. No precipitation was recorded during the second half of the month, the total, 1.71 in., fell during the first twelve days, and of this amount 1.48 in. fell during the 24 hour period from the 5th to the 6th. The first killing frost of the season occurred on Nov. 2, and a trace of snow during the afternoon of the first. Only one thunderstorm occurred, lasting about ten minutes. This month was the mildest November since 1904; its predecessor of 1911 had produced the most severe change in temperature on record—a fall of 64° in 24 hours. 77°, the highest temperature, was reached on the 10th, and 25°, the lowest, on the 25th. The mean temperature for the month was 47°, 3° above the normal. 6529 miles of wind were registered, giving for the month an average hourly velocity of 9 miles. The prevailing direction was from the Southeast.

December, 1912.

December, 1912, ranks as the mildest winter month experienced in St. Louis. There were ten days of 100% sunshine; the temperature was confined within moderate ranges, and precipitations were of short duration. Only .10 in. of snow was recorded, as against 5 in. for December, 1911, while the total precipitation of .59 in. was far below the normal for the month of 2.23 in. This low precipitation was exceeded but three times in 75 years. The thermometer reached its maximum of 65° on the 5th, a minimum of 12° on the 12th, and recorded a mean 4° above the normal. The mean relative humidity of 54° was the lowest of the year. 7271 miles of wind were recorded, and a maximum velocity of 50 miles an hour on the second. The sunshine register showed 16 clear, 4 partly cloudy and 11 cloudy days. No thunderstorms were recorded.

JANUARY 1912.													
Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	30.19	24	30	14	.0772	.60	.00	.00	.45	P.Cl.	SE	148	⊓' ⊕ ◡
2	30.14	26	30	22	.1060	.78	.00	.00	.20	Cloudy	N	180	⊓'
3	30.18	17	24	9	.0534	.61	.00	.00	.85	Clear	N	180	⊓^{2}
4	30.31	12	20	9	.0386	.55	.00	.00	1.00	Clear	W	382	
5	30.48	5	13	2	.0273	.51	.00	.00	1.00	Clear	NW	293	◡
6	30.39	-1	2	-4	.0233	.65	.00	.72	.25	Cloudy	N	224	
7	30.34	-8	-1	-16	.0164	.60	.00	.00	.07	Cloudy	SE	228	
8	29.77	8	12	-2	.0428	.74	.00	.18	.17	Cloudy	W	293	
9	30.11	15	26	4	.0469	.57	.00	.00	.88	Clear	W	216	⊕
10	30.18	9	17	4	.0405	.71	.00	.00	.62	P.Cl.	N	185	
11	30.30	4	9	-1	.0361	.79	.00	.67	.00	Cloudy	N	332	
12	30.64	-5	0	-9	.0219	.76	.00	.34	1.00	Clear	N	293	
13	30.36	5	13	-9	.0312	.63	.00	.00	.55	P.Cl.	SE	191	
14	30.16	20	23	12	.0811	.78	.00	.01	.00	Cloudy	NW	220	
15	30.48	0	21	-5	.0236	.61	.00	T	1.00	Clear	NW	300	C.W.
16	30.13	12	19	-2	.0400	.58	.00	.00	.40	P.Cl.	SE	307	
17	29.78	41	44	19	.2090	.80	.00	.00	.00	Cloudy	SE	310	
18	29.97	29	49	25	.1310	.84	.32	.03	.00	Cloudy	N	302	Δ'
19	30.35	14	26	9	.0521	.67	.00	.00	1.00	Clear	NW	196	
20	30.27	27	32	15	.1001	.68	.00	T	.72	Clear	W	261	
21	30.24	37	51	19	.1153	.58	.00	.00	.87	Clear	W	170	⊓'
22	30.01	48	57	38	.1850	.57	.00	.00	.77	Clear	W	201	⊓'
23	30.01	45	52	36	.1980	.69	.00	.00	.82	Clear	W	160	
24	30.10	33	45	30	.1138	.61	.00	.00	.21	Cloudy	N	123	⊓^{2}
25	29.91	31	34	28	.1300	.75	.00	.00	.00	Cloudy	SE	192	◡
26	29.67	38	47	28	.1723	.77	.00	.00	.87	Clear	W	173	⊓^{2} ≡^{2}
27	29.90	32	42	31	.1383	.76	.00	.00	.01	Cloudy	E	189	
28	29.72	35	39	32	.1773	.87	.00	.00	.00	Cloudy	SE	266	≡'
29	29.95	27	36	22	.0931	.64	.00	.00	.03	Cloudy	NW	325	◠
30	30.08	25	30	20	.0777	.60	.00	T	.50	P.Cl.	NW	284	⊓^{2}
31	30.04	31	41	19	.1173	.69	.00	.00	.33	P.Cl.	W	190	
	30.13	20^5	28^5	13	.0873	.68	.32	1.95	.47		W	7314	

FEBRUARY 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	30.00	26	40	23	.0850	.62	.00	.02	.23	Cloudy	NW	481	
2	30.08	15	23	7	.0404	.53	.00	T	.87	Clear	NW	258	⌓
3	30.08	10	21	2	.0524	.74	.00	.84	.25	Cloudy	NW	374	
4	30.39	6	16	-9	.0305	.60	.00	.00	.84	Clear	W	291	C.W. ⊕
5	30.33	13	16	10	.0567	.80	.00	T	.26	Cloudy	NW	260	
6	30.30	18	22	14	.0708	.76	.00	.01	.00	Cloudy	W	176	
7	30.09	23	28	19	.0816	.69	.00	.00	.43	P.Cl.	W	213	⊓'
8	30.20	20	24	17	.0622	.60	.00	.00	.05	Cloudy	NW	176	
9	30.17	15	22	9	.0420	.52	.00	.00	.64	P.Cl.	N	203	⊕
10	30.03	18	27	5	.0519	.56	.00	.00	.70	Clear	SE	163	≡'
11	29.89	33	42	23	.1053	.56	.00	T	.14	Cloudy	NW	208	
12	30.26	25	35	20	.0886	.66	.00	.00	.40	P.Cl.	NW	166	
13	30.32	27	33	18	.1046	.73	.00	.00	.33	P.Cl.	SE	152	⊕
14	30.22	35	41	29	.1323	.65	.00	.00	.31	P.Cl.	N	126	
15	30.01	38	46	29	.1650	.74	.00	.00	.75	Clear	NW	78	⊕
16	29.82	43	52	32	.1790	.68	.00	.00	.70	P.Cl.	W	99	
17	29.69	47	55	36	.1800	.58	.00	.00	.50	P.Cl.	SE	155	
18	29.71	50	60	36	.1820	.56	T	.00	.60	P.Cl.	W	139	
19	29.88	42	46	40	.2040	.76	.00	.00	.06	Cloudy	N	154	
20	29.97	31	40	29	.1430	.82	T	1.00	..00	Cloudy	N	245	⊓' ≡'
21	29.60	25	29	24	.1150	.87	.00	1.55	.00	Cloudy	NW	514	Blizzard
22	30.09	26	34	18	.0833	.62	.00	.00	1.00	Clear	W	263	
23	30.02	39	46	26	.1216	.54	.00	.00	.51	P.Cl.	SE	256	⊕
24	30.00	42	48	36	.1850	.70	.18	.00	.06	Cloudy	SE	144	≡^{2}
25	29.90	38	45	36	.2040	.90	.30	.00	.00	Cloudy	E	173	≡'
26	29.64	30	39	25	.1400	.80	.68	T	.00	Cloudy	NW	349	
27	30.06	27	36	18	.0890	.62	.00	.00	1.00	Clear	W	171	
28	30.21	30	34	28	.1034	.64	.00	.00	.11	Cloudy	N	174	⊓^{2} ⊕ ⌓
29	30.39	25	32	21	.0819	.64	.00	T	.88	Clear	NW	201	
	30.08	28^2	35^6	21^4	.1096	.67	1.16	3.42	.41		NW	6362	

MARCH 1912

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	30.62	24	30	17	.0754	.60	.00	.00	.75	Clear	N	131	
2	30.49	20	29	18	.0874	.85	.00	.62	.00	Cloudy	E	171	
3	30.32	27	31	20	.1084	.76	.00	.13	.43	P.Cl.	N	151	⌓
4	30.44	26	30	18	.0905	.68	.00	.00	.24	Cloudy	N	152	
5	30.46	25	30	18	.0875	.68	.00	T	.30	Cloudy	N	212	Distant ϟ
6	30.22	28	36	16	.0986	.66	.00	.00	.68	P.Cl.	E	111	$\equiv^1$
7	30.04	34	35	29	.1790	.92	.03	.20	..00	Cloudy	E	88	$\equiv^2$all day
8	30.13	32	36	29	.1480	.83	.01	.01	.00	Cloudy	N	250	
9	30.38	24	29	18	.0592	.50	.00	.03	1.00	Clear	NW	219	
10	30.30	25	30	18	.0673	.51	.00	.00	.11	Cloudy	SE	140	
11	29.82	32	35	25	.1720	.93	.01	.80	.00	Cloudy	SE	250	$\equiv^2$
12	29.87	33	36	31	.1550	.82	.04	T	.00	Cloudy	N	256	$\equiv^1$ Δ
13	30.09	30	36	21	.1064	.66	.00	.00	.46	P.Cl.	NW	134	$\sqcap^2$
14	29.75	39	42	33	.2040	.85	.17	.00	.00	Cloudy	SE	239	$\equiv^2$
15	29.93	30	41	28	.1280	.78	.01	T	.18	Cloudy	NW	309	
16	30.20	37	45	26	.1470	.67	.00	.00	.91	Clear	SE	274	$\sqcap^2$ ⊕
17	30.02	53	65	39	.2140	.54	.00	.00	.85	Clear	SE	314	⊕
18	30.10	49	59	34	.2030	.61	.00	.00	.80	Clear	SE	192	$\sqcap^2$ $\equiv^2$
19	29.80	59	73	46	.3576	.72	T	.00	.62	P.Cl.	S	156	$\underline{⌓^2}$
20	29.91	36	57	33	.1833	.87	.15	.00	.00	Cloudy	E	164	ϟ $\blacktriangle^0$
21	30.24	26	35	25	.1046	.75	.40	T	.00	Cloudy	NW	326	
22	30.41	28	33	21	.1020	.67	.00	.00	.73	Clear	E	156	⊕
23	30.02	35	37	30	.1617	.80	.00	.05	.03	Cloudy	NE	141	Δ^2
24	29.91	32	36	28	.1366	.79	.00	1.53	.20	Cloudy	N	375	Blizzard
25	30.04	35	47	20	.1323	.66	.00	.00	.90	Clear	SE	156	$\equiv^1$ $\sqcap^2$
26	29.98	44	52	38	.1873	.64	.00	.00	1.00	Clear	W	167	⌓
27	29.96	42	47	35	.2267	.86	.07	.00	.03	Cloudy	NE	97	
28	29.60	46	49	40	.2960	.94	.49	.00	.00	Rain'g	NE	148	$\equiv^2$ ϟ
29	29.75	51	60	41	.2333	.65	.68	.00	.63	P.Cl.	N	216	
30	30.09	54	68	37	.2937	.71	.00	.00	.61	P.Cl.	SE	232	
31	30.03	64	75	53	.3007	.52	.00	.00	.65	P.Cl.	S	163	⌓ ⌓
	30.09	36	43⁴	28⁶	.1628	.72	2.06	3.37	.40		N	6090	

APRIL 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Direction of Wind.	Total Mileage.	Miscellaneous Phenomena.
1	29.75	52	69	43	.3710	.94	.12		.00	Cloudy	SE	196	≡^{1}
2	29.83	46	54	34	.1797	.62	.83	T	.40	P.Cl.	NW	279	
3	30.17	49	59	37	.1963	.57	.00		.83	Clear	SE	134	
4	30.12	64	75	48	.2307	.43	.00		.85	Clear	SE	233	⊕
5	29.91	69	79	59	.3043	.44	.00		.83	Clear	SE	310	
6	29.78	64	72	56	.3990	.67	.57		.08	Cloudy	S	323	☈
7	30.28	47	59	39	.1343	.44	.00		1.00	Clear	NW	297	
8	30.29	54	62	41	.1780	.45	.00		1.00	Clear	SE	173	
9	30.00	61	72	46	.1890	.37	T		.60	P.Cl.	SW	169	
10	29.94	62	69	50	.2993	.57	.00		.93	Clear	SE	125	≡^{0}
11	29.87	69	77	55	.3927	.58	.00		.92	Clear	SE	147	⌓^{1} ≡^{1}
12	29.77	60	73	58	.4740	.88	1.29		.17	Cloudy	SE	164	☈ 11:54AM
13	29.61	66	70	58	.5253	.83	.05		.51	P.Cl.	SE	309	
14	29.60	70	81	56	.2040	.31	.60		1.00	Clear	S	212	☈▲^{1}10:30PM
15	29.87	64	74	57	.2810	.47	.00		1.00	Clear	N	164	⊕
16	29.98	51	66	47	.2960	.79	.09		.30	Cloudy	N	236	
17	29.76	39	52	38	.2253	.93	.86		.00	Cloudy	NW	325	ϟ9:10PM
18	29.92	46	54	35	.2063	.69	.00		.20	Cloudy	NW	247	
19	30.04	50	56	41	.2400	.67	.04		.17	Cloudy	E	76	≡^{2} ◓^{2}
20	29.89	58	67	47	.3517	.73	.00		.72	Clear	SE	263	⊕ ◒
21	29.59	66	74	55	.4733	.74	.08		.51	P.Cl.	S	364	☈ 2AM & 6PM
22	29.91	50	69	44	.2577	.72	T		.39	P.Cl.	NW	347	
23	30.21	58	68	44	.2470	.54	.00		.85	Clear	W	114	
24	30.21	65	76	52	.2733	.47	.00		.96	Clear	W	130	⊕ ◓
25	30.09	59	71	54	.3663	.74	.53		.10	Cloudy	SE	432	☈ 4:30PM
26	29.85	63	77	54	.4493	.79	1.96		.54	P.Cl.	SE	318	☈ ▲ ◒
27	30.19	59	69	51	.2973	.60	.00		.90	Clear	NE	198	⊕ ◓,
28	29.71	62	70	52	.5017	.87	.57		.00	Cloudy	SE	238	☈ 2:45AM
29	29.75	48	63	46	.2963	.89	.07		.00	Cloudy	NW	250	≡^{1}
30	29.95	54	61	46	.3203	.76	T		.92	Clear	SE	299	⌓^{1}
	29.93	57^{3}	68^{0}	48^{0}	.3053	65%	7.66	T	.56		SE	7002	

MAY 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.88	66	78	52	.4917	.76	.01		.54	P.Cl.	SE	274	ϟ ◓
2	29.84	77	85	63	.5263	.59	.00		1.00	Clear	SE	216	
3	29.84	74	81	65	.5823	.69	.00		.71	Clear	SE	205	
4	29.74	75	82	66	.6140	.71	.00		.95	Clear	SE	250	ϟ
5	29.75	74	82	67	.4973	.63	.00		.85	Clear	W	129	⌓^{0}
6	29.79	75	84	67	.6537	.76	.00		.45	P.Cl.	SE	157	
7	29.80	73	81	62	.4933	.62	.00		.92	Clear	NW	146	⌓^{2}
8	29.75	73	82	63	.4040	.51	.00		.92	Clear	W	165	
9	29.82	72	79	60	.3653	.46	.00		1.00	Clear	NE	127	⌓^{1}
10	29.68	70	77	60	.4933	.67	T		.57	P.Cl.	SE	387	ϟ 8PM
11	29.40	61	74	58	.4713	.87	2.06		.08	Cloudy	SE	233	Tϟ 3 in all
12	29.89	52	60	49	.2983	.79	.40		.02	Cloudy	NW	337	
13	30.19	58	67	44	.2950	.63	.00		.88	Clear	NW	97	⌓^{2} ⊕ .02 in all.
14	30.04	59	65	52	.2840	.57	.00		.80	Clear	W	130	
15	29.73	55	63	52	.3003	.71	.03		.17	Cloudy	S	153	
16	29.76	52	58	44	.2980	.79	.04		.32	Cloudy	NW	308	
17	30.08	60	69	48	.2893	.56	.00		1.00	Clear	W	193	
18	30.11	69	79	52	.4140	.58	.00		1.00	Clear	S	191	
19	30.07	76	85	62	.5110	.59	.00		1.00	Clear	S	225	
20	29.94	77	85	67	.4717	.52	.00		1.00	Clear	S	304	
21	29.89	77	86	66	.4730	.55	.00		1.00	Clear	S	226	◓ ◒
22	29.80	79	87	67	.5893	.61	.00		1.00	Clear	SE	340	
23	29.81	80	89	71	.5887	.58	.00		.90	Clear	S	267	◓
24	29.96	74	83	69	.6103	.73	.07		.27	Cloudy	N	141	Tϟ 3A, 7:30PM.
25	30.02	74	80	66	.5770	.70	.05		.47	P.Cl.	E	133	
26	29.93	77	84	69	.6993	.76	T		.65	P.Cl.	SE	220	Tϟ 2PM, SW
27	29.62	80	88	68	.5553	.55	.00		.80	Clear	S	365	◓
28	29.49	71	82	62	.5303	.72	1.64		.50	P.Cl.	S	265	Tϟ 1:15AM
29	29.82	65	74	62	.5000	.81	.00		.25	Cloudy	N	240	
30	30.06	63	70	52	.4457	.77	.00		.72	Clear	SE	135	⌓^{2}
31	30.00	71	78	60	.5070	.68	.00		1.00	Clear	SE	200	
	29.85	69^{7}	78°	60°	.4784	66%	4.30	.00	70%		SE	6759	

JUNE 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.89	75	87	66	.6117	.71	.04		.57	P.Cl.	SE	217	☈ ⌒
2	29.94	69	77	58	.4653	.67	.00		1.00	Clear	W	203	
3	29.92	77	86	62	.5000	.56	.00		1.00	Clear	S	143	⌓¹
4	30.06	71	82	61	.4153	.58	T		.90	Clear	N	190	☈
5	29.98	71	77	60	.4957	.64	.13		.35	Cloudy	SE	177	☈
6	30.08	70	74	64	.4337	.61	1.06		.81	Clear	N	246	
7	30.20	66	72	55	.3307	.54	.00		.95	Clear	N	197	
8	30.21	62	69	51	.2267	.51	.00		.57	P.Cl.	E	126	
9	30.21	67	70	60	.3437	.53	T		.34	Cloudy	E	182	
10	30.17	73	80	65	.4313	.52	.00		.65	P.Cl.	SE	221	
11	30.10	75	83	64	.4180	.48	.00		1.00	Clear	SE	161	
12	29.94	79	87	65	.5093	.52	.00		.96	Clear	SE	134	
13	29.72	74	82	69	.6053	.71	.04		.21	Cloudy	SE	174	
14	29.52	73	80	67	.6120	.77	1.77		.21	Cloudy	S	203	☈
15	29.52	76	83	63	.7397	.84	.97		.59	P.Cl.	SE	211	☇
16	29.74	71	80	66	.7203	.96	3.98		.00	Cloudy	S	203	☈ all day
17	29.99	61	69	59	.5010	.94	.50		.03	Cloudy	N	174	☈ d.n.
18	30.00	59	61	56	.4540	.91	.23		.00	Cloudy	N	187	
19	30.03	64	70	55	.4220	.71	.14		.66	P.Cl.	NW	204	
20	30.00	71	79	58	.4667	.62	.00		.96	Clear	W	242	
21	30.06	71	78	61	.5000	.67	T		.60	P.Cl.	N	109	
22	30.17	70	78	58	.3890	.55	.00		.93	Clear	E	92	
23	30.13	74	81	61	.4343	.55	.00		1.00	Clear	N	108	
24	30.05	76	84	64	.4820	.56	.00		.90	Clear	N	63	
25	29.95	75	86	66	.5980	.70	.00		.41	P.Cl.	N	105	
26	29.90	79	89	67	.6250	.66	.00		.81	Clear	S	83	≡² ⌓² ⏀
27	29.91	76	86	69	.6030	.69	.01		.42	P.Cl.	SE	94	☈ 5:30PM
28	29.99	78	83	68	.6257	.66	T		.72	Clear	SE	140	☈ 12:50PM
29	30.02	75	83	70	.6533	.78	.01		.40	P.Cl.	SE	123	☈ 4:50PM
30	29.98	77	82	69	.6460	.70	.00		.60	P.Cl.	SE	133	
	29.98	72°	79°	62°	.5086	66%	8.88	.00	62%		SE	4845	

JULY 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.96	73	81	69	.6763	.82	.05		.50	P.Cl.	SE	180	⛈ 12:40PM
2	30.01	76	83	69	.7660	.84	.52		.14	Cloudy	S	197	
3	30.03	72	83	69	.6923	.88	.27		.07	Cloudy	SE	168	⛈ 4:00PM
4	29.92	85	92	70	.8010	.69	.00		.88	Clear	S	122	
5	29.93	86	92	75	.7403	.62	.00		.73	Clear	W	110	
6	29.94	79	89	74	.7580	.78	.00		.20	Cloudy	SE	106	T and ⚡
7	29.96	79	88	70	.7403	.75	.25		.64	P.Cl.	S	133	⛈ 12:15PM
8	29.95	83	92	73	.7667	.69	.00		.88	Clear	S	158	
9	29.95	85	91	75	.7750	.66	.00		.82	Clear	S	188	
10	29.93	77	87	66	.7853	.85	.55		.14	Cloudy	S	168	⛈ 4:00PM ▲^{2}
11	29.92	80	87	67	.6687	.68	.01		.73	P.Cl.	W	87	
12	29.86	81	87	72	.8397	.79	.36		.20	Cloudy	S	122	⛈ 9:40AM
13	29.88	86	94	75	.8497	.70	.00		.80	Clear	S	186	Distant ⚡
14	29.95	85	94	68	.8497	.72	3.17		.80	Clear	S	151	⛈ 2AM
15	29.98	83	89	77	.8303	.74	.00		.70	P.Cl.	N	168	⛈ 2PM.
16	30.02	76	84	64	.6270	.69	.00		.40	P.Cl.	N	142	
17	29.99	79	88	69	.7760	.78	.98		.45	P.Cl.	N	118	⛈ 2:15AM
18	30.03	79	86	72	.6863	.71	.00		.96	Clear	N	196	
19	30.12	73	79	64	.4890	.62	.00		.85	Clear	E	173	
20	29.93	81	89	66	.7320	.69	.00		.93	Clear	S	199	
21	29.92	82	88	78	.8760	.80	.06		.30	Cloudy	W	191	⛈
22	30.04	79	87	72	.8153	.81	.00		.20	Cloudy	SE	163	
23	29.91	87	95	77	.8483	.67	.00		.97	Clear	S	177	
24	29.81	89	96	80	.8500	.63	.00		1.00	Clear	W	232	
25	29.88	83	90	77	.6690	.60	.00		.76	Clear	N	201	
26	29.97	79	86	70	.5683	.58	.00		1.00	Clear	N	128	
27	30.00	78	86	67	.5633	.58	.00		1.00	Clear	SE	139	
28	29.87	83	93	71	.7030	.62	.00		.63	P.Cl.	W	183	⛈
29	29.86	80	86	73	.5950	.59	.00		.98	Clear	NW	196	
30	29.84	80	89	67	.6050	.60	.00		.35	P.Cl.	W	154	
31	29.86	76	84	67	.4600	.53	.00		.63	P.Cl.	NW	167	
	29.95	80°	88°	71°	.7227	70%	6.22		63%		S	5003	

AUGUST 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.92	74	82	66	.5120	.64	T		.40	P.Cl.	N	137	
2	29.99	73	80	64	.4220	.54	T		.47	P.Cl.	N	139	
3	30.09	65	74	56	.3660	.61	.55		.81	Clear	N	140	Lowest since 1842
4	30.17	65	73	55	.3647	.61	.00		.68	P.Cl.	NE	116	
5	30.13	68	75	58	.4127	.60	.00		.71	P.Cl.	SE	135	Coolest 5th
6	30.00	74	81	62	.5130	.63	T		.40	P.Cl.	SE	193	on record. Ꞧ 7:45
7	29.89	73	80	65	.6730	.82	.12		.14	Cloudy	S	110	Ꞧ PM
8	29.81	72	78	68	.6923	.88	.25		.22	Cloudy	S	129	Ꞧ
9	29.78	71	79	64	.5843	.78	.02		.26	Cloudy	W	174	Ꞧ ≡°
10	29.79	68	80	61	.5060	.67	T		.28	Cloudy	W	222	≡'
11	29.79	80	89	67	.6197	.61	.00		.86	Clear	W	111	
12	29.86	75	84	69	.6780	.83	.43		.12	Cloudy	S	165	Ꞧ 8:45AM
13	30.00	81	93	73	.7320	.72	T		.74	Clear	W	205	Ꞧ 6PM
14	30.07	77	84	69	.6553	.72	.20		.37	Cloudy	W	97	Ꞧ d.n.
15	30.01	77	81	71	.6553	.72	.00		.19	Cloudy	SE	99	
16	29.98	78	86	69	.6897	.75	T		.48	P.Cl.	SE	88	ϟ
17	29.97	83	92	74	.8020	.71	T		.80	Clear	S	113	ϟ
18	29.94	85	93	75	.7490	.63	.00		.90	Clear	W	158	
19	29.87	86	94	77	.7580	.63	.00		.71	Clear	S	181	
20	29.90	79	88	75	.7490	.76	.18		.15	Cloudy	W	162	Ꞧ 4AM
21	29.83	78	84	71	.6933	.74	.25		.33	Cloudy	W	170	Ꞧ d.n.
22	29.70	76	87	65	.5430	.63	T		.80	Clear	W	215	ϟ
23	29.85	76	85	64	.4953	.57	.00		1.00	Clear	W	158	⌓°
24	29.84	82	92	71	.5453	.51	.00		1.00	Clear	S	219	
25	29.78	83	90	72	.6933	.62	.21		.56	P.Cl.	S	247	Ꞧ 8AM
26	29.82	82	90	65	.6600	.61	.46		.80	Clear	N	153	Ꞧ d.n.
27	30.00	74	87	67	.4880	.60	.00		1.00	Clear	SE	178	
28	29.79	86	96	69	.7320	.60	.00		1.00	Clear	SW	227	ϟ
29	29.83	83	93	73	.7260	.64	.01		.60	P.Cl.	W	144	Ꞧ M ∩
30	29.86	84	92	74	.7323	.64	.00		.69	P.Cl.	S	167	
31	29.88	86	94	78	.7070	.58	.00		.86	P.Cl.	S	193	
	29.91	77°	85'	68°	.6167	66%	2.68		60%		W	4945	

SEPTEMBER 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.89	86	95	76	.6690	.55	.00		.98	Clear	S	205	
2	29.93	83	94	76	.7160	.64	T		.73	Clear	S	151	☈ 1:15PM
3	29.95	86	93	75	.7403	.63	.00		.75	Clear	SW	101	☇
4	29.95	87	95	76	.6853	.56	.00		.98	Clear	S	119	☇
5	29.98	87	96	77	.5917	.48	.00		1.00	Clear	S	103	☇
6	29.95	88	97	77	.5653	.45	.00		.89	Clear	S	76	
7	29.86	85	96	74	.5980	.52	.00		.62	P.Cl.	N	68	
8	29.78	86	96	74	.5630	.49	.00		1.00	Clear	SE	132	
9	29.87	85	93	76	.6343	.55	.00		.83	Clear	SE	167	≡•
10	29.96	87	95	74	.5520	.48	.00		.77	Clear	SE	98	
11	30.04	80	90	73	.5957	.59	.00		1.00	Clear	N	196	
12	30.05	71	80	62	.2820	.38	.00		.78	Clear	NE	108	
13	29.82	72	80	61	.3840	.51	T		.52	P.Cl.	SE	107	
14	29.84	77	85	68	.5890	.65	.17		.24	Cloudy	SE	142	☈
15	29.99	72	77	69	.6390	.81	.06		.15	Cloudy	NW	143	☇
16	30.01	71	78	65	.5750	.76	.00		.20	Cloudy	NW	120	☇
17	29.84	62	72	61	.5117	.92	1.06		.00	Cloudy	NW	115	☈ 1:20AM
18	29.86	59	64	55	.3200	.66	.00		.50	P.Cl.	W	217	⌓^{2}
19	29.91	63	73	48	.3073	.56	.00		1.00	Clear	W	192	⌓^{1}
20	29.84	68	75	60	.5067	.72	.10		.26	Cloudy	S	206	☈ 9PM
21	29.92	57	71	54	.4270	.92	1.20		.00	Cloudy	W	126	☈
22	29.94	65	73	55	.3137	.58	.00		1.00	Clear	W	94	≡^{2}⌓^{2}
23	29.92	66	73	53	.2487	.52	.00		1.00	Clear	E	126	≡^{2}⌓^{2}
24	29.81	67	76	55	.4340	.66	.00		1.00	Clear	SE	200	≡^{2}⌓^{2}
25	29.97	59	71	53	.3830	.76	.02		.27	Cloudy	W	263	☇
26	30.21	53	60	42	.2933	.58	.00		1.00	Clear	N	109	⌓^{2}
27	30.21	59	67	47	.2170	.46	.00		1.00	Clear	E	128	⌓^{2}
28	30.18	61	70	50	.2717	.54	.00		.95	Clear	N	150	≡^{2}
29	30.36	51	60	45	.2537	.69	.00		.02	Cloudy	N	198	
30	30.24	53	62	42	.2063	.52	.00		.83	Clear	W	97	⌓^{1}
	29.97	71°	80°	62°	.4691	61%	2.61	0.00	68%		SE	4257	

OCTOBER 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of sunshine.	Character of Day.	Prevailing Wind. Direction.	Total Mileage.	Miscellaneous Phenomena.
1	30.16	57	68	43	.2380	.55	.00		1.00	Clear	SE	94	≡^{2} ⌓^{2}
2	30.09	62	72	48	.2747	.55	.00		1.00	Clear	SE	142	⌓^{2}
3	29.88	68	79	55	.3567	.53	.01		.60	P.Cl.	W	155	
4	29.96	69	79	56	.3763	.57	.00		1.00	Clear	SE	113	≡^{2} ⌓^{2}
5	30.06	74	85	60	.4230	.54	.00		1.00	Clear	SE	177	≡^{1} ⌓^{2}
6	30.02	76	86	63	.5300	.60	.00		1.00	Clear	S	157	⌓^{0} ↯
7	30.13	58	79	53	.2737	.57	T		.74	P.Cl.	N	232	
8	29.92	61	68	53	.3343	.62	.02		.01	Cloudy	SE	203	
9	29.79	75	85	66	.5973	.69	.16		.57	P.Cl.	S	257	☈ 10:30AM
10	29.94	73	79	67	.6093	.77	.09		.18	Cloudy	SE	174	☈ 4:45AM
11	29.80	75	84	64	.5237	.65	.00		.65	P.Cl.	S	312	☈ distant
12	30.14	55	75	49	.2303	.55	.00		.73	P.Cl.	W	257	
13	30.30	58	68	45	.2256	.51	.00		.54	P.Cl.	W	106	
14	30.27	60	69	46	.1983	.42	.00		.72	Clear	W	78	≡^{0}
15	30.34	62	73	49	.2407	.46	.00		1.00	Clear	N	98	≡^{1} ◓
16	30.25	61	70	49	.2203	.44	.00		.64	P.Cl.	SE	104	≡^{1} ◓
17	29.93	61	69	53	.3663	.69	.00		.18	Cloudy	SE	164	
18	29.77	68	73	61	.5750	.84	.12		.05	Cloudy	SE	175	
19	30.14	55	68	48	.1750	.41	.00		1.00	Clear	NW	166	
20	29.99	56	67	44	.2056	.49	.00		.90	Clear	SE	282	
21	29.84	66	78	50	.4173	.67	.00		.80	Clear	SE	222	≡^{2} ⌓^{2} ◓☈
22	30.08	48	70	45	.2033	.61	.60		.52	P.Cl.	NW	328	☈
23	30.22	47	56	36	.1703	.54	.00		1.00	Clear	N	101	≡^{0} ⊓^{1}
24	30.17	51	59	40	.1850	.51	.00		.95	Clear	SE	119	≡^{2}
25	30.10	56	65	46	.2110	.49	.00		.40	Smoky	W	82	◓
26	30.09	60	69	47	.2663	.54	.00		.70	Clear	NW	72	Dense smoke.
27	30.03	63	77	49	.2733	.50	.00		1.00	Clear	SE	130	
28	29.86	64	75	54	.2703	.49	.00		1.00	Clear	SE	239	◓
29	29.82	62	72	57	.2997	.52	T		.29	Cloudy	W	246	
30	30.12	49	57	43	.2000	.57	T		.30	Cloudy	N	106	
31	29.79	46	52	43	.2803	.91	1.46		.00	Cloudy	N	186	↯ ≡^{1}
	30.04	62°	71°	51°	.3081	57%	2.46	.00	66%		SE	5295	

NOVEMBER 1912.

Date.	Mean Atmospheric Pressure.	Mean Temperature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches,	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	30.10	39	44	35	.1530	.65	.14	T	.19	Cloudy	NW	275	
2	30.22	36	42	29	.1088	.52	.00		.95	Clear	NW	158	≡^{0} Killing frost.
3	30.16	44	54	32	.1413	.52	.00		.50	P.Cl.	SE	245	⊓^{2}
4	30.01	55	65	44	.2347	.55	.00		.80	Clear	S	332	
5	30.01	54	57	49	.3737	.90	1.28		.00	Cloudy	SE	238	≡^{2}
6	29.84	54	56	51	.3590	.85	.20		.05	Cloudy	N	202	≡^{2}
7	30.00	49	58	39	.2123	.59	.00		1.00	Clear	N	120	≡^{2} ⌓^{2}
8	30.13	55	63	45	.1597	.41	.00		1.00	Clear	W	282	
9	30.26	52	61	41	.1463	.41	.00		.75	Clear	SE	189	≡^{2} ⊓^{1}
10	29.95	65	77	52	.2437	.41	.00		1.00	Clear	S	215	
11	29.88	66	75	57	.3140	.51	.00		.50	P.Cl.	SE	313	
12	29.76	62	72	57	.3583	.61	.09		.50	P.Cl.	SE	329	T↘ 5:45
13	29.93	45	59	42	.2113	.72	T		.20	Cloudy	W	327	
14	30.11	40	47	37	.1500	.60	.00		.60	P.Cl.	NW	208	
15	30.30	41	48	31	.1303	.55	.00		.61	P.Cl.	SE	110	≡^{2} ⊓^{2}
16	30.43	43	54	37	.1713	.62	.00		1.00	Clear	NW	167	≡^{2}
17	30.45	42	52	31	.1293	.53	.00		1.00	Clear	NW	143	⊓^{2}
18	30.19	50	62	36	.1310	.39	.00		1.00	Clear	S	159	≡^{1}
19	29.97	58	66	46	.1953	.42	.00		1.00	Clear	W	163	≡^{1}
20	29.93	60	71	48	.1873	.39	.00		1.00	Clear	SE	205	≡^{0}
21	30.09	52	61	48	.1980	.52	.00		.50	P.Cl.	NW	165	≡^{2}
22	30.08	48	58	36	.1313	.43	.00		.70	Clear	W	128	⌓ ⊓^{1}
23	29.86	44	53	41	.1317	.46	.00		.30	Cloudy	NW	327	
24	30.14	34	41	27	.1100	.58	.00		.60	P.Cl.	NW	379	
25	30.19	34	42	25	.0865	.45	.00		.01	Cloudy	W	110	⊓^{2}
26	30.16	37	43	30	.1124	.56	.00		.57	P.Cl.	NW	232	≡^{0}
27	30.31	32	38	28	.1113	.63	.00		.60	P.Cl.	W	212	
28	30.17	37	47	26	.0897	.45	.00		.95	Clear	SE	205	⌓ ⊓^{2}
29	30.15	44	53	35	.1207	.43	.00		.74	Clear	S	178	Dense smoke
30	30.21	46	51	35	.1797	.59	.00		.00	Cloudy	SE	213	" "
	30.10	47°	55°	39°	.1794	65%	1.71	T	62%		SE	6529	

DECEMBER 1912.

Date.	Mean Atmospheric Pressure.	Mean Temparature F°.	Maximum Temperature F°.	Minimum Temperature F°.	Mean Vapor Pressure.	Relative Humidity.	Rain in Inches.	Melted Snow in Inches.	Percentage of Sunshine.	Character of Day.	Prevailing Wind Direction.	Total Mileage.	Miscellaneous Phenomena.
1	29.93	54	59	47	.3116	.74	.19		.26	Cloudy	SE	356	
2	30.06	38	58	36	.1230	.53	.13		.66	P.Cl.	W	335	
3	29.97	42	51	32	.1780	.68	.00		.25	Cloudy	SE	183	⌓ ⊓^{2}
4	29.88	49	54	44	.2230	.64	T		.27	Cloudy	SE	163	≡^{2} Dense smoke.
5	29.77	59	65	51	.3796	.79	.01		.17	Cloudy	SE	244	≡^{2}
6	30.35	29	61	24	.0878	.57	.00		.26	Cloudy	W	285	
7	30.13	38	47	28	.0867	.41	.00		1.00	Clear	SW	213	
8	30.30	28	43	21	.0933	.57	.00		.36	P.Cl.	NW	319	
9	30.28	27	36	14	.0491	.39	.00		1.00	Clear	S	190	≡^{2} ⊓^{2}
10	29.89	42	50	30	.1350	.50	.00		.93	Clear	NW	272	
11	30.25	28	40	25	.0740	.52	.00		.73	Clear	NW	272	
12	30.57	19	25	12	.0377	.39	.00		1.00	Clear	NW	211	
13	30.23	40	50	21	.1006	.42	.00		1.00	Clear	S	204	
14	30.01	44	53	33	.1600	.54	.00		1.00	Clear	S	161	
15	29.91	48	54	40	.1503	.47	.00		1.00	Clear	W	276	
16	29.78	44	49	34	.1683	.60	T		.03	Cloudy	SE	259	≡^{2}
17	29.69	45	52	42	.1653	.57	.24		.92	Clear	W	269	⌓
18	29.95	31	43	31	.1383	.73	T	T	.00	Cloudy	W	247	
19	29.89	37	45	28	.1167	.55	.00		.66	P.Cl.	W	273	Meteor.
20	30.12	36	46	33	.0986	.48	.00		.70	Clear	W	270	
21	30.39	34	41	25	.0811	.44	.00		.97	Clear	W	127	≡^{1}
22	30.37	33	39	26	.0856	.46	.00		.32	Cloudy	W	112	
23	30.05	36	41	30	.0960	.48	.00		.00	Cloudy	SE	97	≡^{1}
24	30.02	41	52	26	.0948	.41	.00		1.00	Clear	SW	181	≡^{1} ⊓^{1}
25	30.07	42	50	33	.1158	.46	.00		1.00	Clear	S	240	
26	30.04	36	43	35	.1523	.66	T	.10	.00	Cloudy	W	254	
27	30.24	29	35	24	.0891	.57	.01		1.00	Clear	W	240	
28	30.03	43	59	31	.1010	.36	.00		1.00	Clear	SE	206	
29	29.80	40	49	37	.1830	.75	.01		.00	Cloudy	SE	282	
30	29.73	41	49	31	.0933	.37	.00		.75	Clear	S	320	
31	29.87	43	46	40	.1250	.46	.00		.32	Cloudy	NW	210	≡^{2}
	30.05	38°	48°	31°	.1320	54%	0.59	.10	60%		W	7271	

MONTHLY AND ANNUAL METEOROLOGICAL SUMMARY 1912.

	ATMOSPHERIC PRESSURE.			TEMPERATURE					MOISTURE				WIND			WEATHER					MISCELLANEOUS PHENOMENA.								
	Mean	Highest	Lowest	Maximum	Minimum	Mean Maximum	Mean Minimum	Monthly Mean	Mean Vapor Pressure	Relative Humidity	Rain and Snow	Snow (unmelted).	Prevailing Direction	Total Mileage	Mean Hourly Velocity	Hours of Sunshine	Average Daily Sunshine	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days	Thunderstorms. ☈	Hail ▲	Solar Halos ⊕	Lunar Halos ⊖	Sleet △	Fog ≡	Heavy Frost ⊓	Killing Frost	Date
JANUARY	30.12	30.65	29.62	57°	-16	28.5	13.0	20.8	0.0878	68%	2.27	19.5	W	mi. 7314	10	125	47%	12	14	5	0	0	2	3	1	2	8	0	0
FEBRUARY	30.08	30.48	29.36	60	-9	35.6	21.4	28.2	0.1096	67	4.58	34.2	NW	6362	9	120	41	7	9	13	0	0	6	0	0	4	1	0	0
MARCH	30.09	30.64	29.43	75	16	43.4	28.6	36.0	0.1628	72	5.43	33.7	N	6090	8	133	40	8	7	16	2	1	3	3	2	8	4	0	0
APRIL	29.93	30.39	29.49	81	34	68.0	48.0	57.5	0.3053	65	7.66	T	SE	7002	10	196	56	14	6	10	7	2	5	2	0	5	0	No formation of frost.	
MAY	29.85	30.21	29.36	89	44	78.0	60.0	69.7	0.4784	66	4.30	00.0	SE	6759	9	283	70	19	6	6	5	0	1	1	0	0	0	0	0
JUNE	29.98	30.26	29.50	89	51	79.3	62.5	72.0	0.5086	66	8.88	00.0	SE	4845	7	270	62	12	13	5	9	0	0	0	0	1	0	0	0
JULY	29.95	30.19	29.72	96	64	88.0	71.0	80.0	0.7227	70	6.22	00.0	S	5003	7	285	63	15	9	7	11	1	0	0	0	0	0	0	0
AUGUST	29.91	30.19	29.67	96	55	85.7	68.0	77.0	0.6177	66	2.68	00.0	W	4945	7	235	60	14	8	9	12	0	0	0	0	2	0	0	0
SEPTEMBER	29.97	30.38	29.75	97	42	80.0	62.0	71.0	0.4691	61	2.61	00.0	SE	4257	6	254	68	19	3	8	5	0	0	0	0	6	0	0	0
OCTOBER	30.04	30.34	29.71	86	36	72.0	51.0	62.0	0.3081	57	2.46	00.0	SE	5295	7	227	66	15	8	8	5	0	0	0	0	10	1	0	0
NOVEMBER	30.10	30.54	29.70	77	25	55.6	39.0	47.3	0.1794	65	1.81	T	SE	6529	9	184	62	14	9	7	1	0	0	0	0	7	6	1	2
DECEMBER	30.05	30.63	29.56	65	12	48.0	31.0	38.6	0.1320	54	0.59	00.1	W	7271	10	171	42	16	4	11	0	0	0	0	0	5	0	0	0
ANNUAL	30.05	30.65	29.36	97	-16	63.5	48.0	55.0	0.3401	65%	49.49	87.5	SE	71672	8	2483	58	165	96	105	57	4	17	9	3	50	20	1	Nov. 2.

Note: MAXIMA AND MINIMA ARE IN ITALICS

PART II.

Seismology

Jesuit Seismological Service Record of the Earthquake Station, St. Louis University.

ST. LOUIS, MO., U. S. A.

Latitude: 38° 38′ 17″ N.
Longitude: 90° 13′ 58″.5 or $6^h. 0^m. 55^s.9$ W. Gr.
Altitude: 160.36 m.

Time: Mean Greenwich, midnight to midnight.
Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Nomenclature: International.

The symbols used in the following records are those of the *International* Nomenclature, which is identical with that given by us in the December Bulletin of the University (1911).

SYMBOLS.

Character of the Earthquake.

I = noticeable, II = striking, III = violent.

d = (terrae motus domesticus) = local earthquake (felt at station).

v = (terrae motus vicinus) = nearby earthquake (less than 1000 km.).

r = (terrae motus remotus) = distant earthquake (1000-5000 km.).

u = (terrae motus ultimus) = very distant earthquake (more than 5000 km.).

PHASES:

P = (undae primae) = first preliminary tremors (longitudinal waves through the earth's interior.)

PRn = P waves reflected n times at the earth's surface.

S = (undae secundae) = second preliminary tremors (transverse waves through the earth's interior).

SRn = S waves reflected n times at the earth's surface.

PS = transformed waves, i. e., waves which, in their reflection at the earth's surface, have been changed from longitudinal to transverse, or vice versa.

L = (undae longae) = long or "Rayleigh" waves (first phase of main or principal portion—surface waves).

M = (undae maximae) = greatest motion in the main or principal portion (complicated surface waves).

C = (cauda) after-shocks or trailers.

F = (finis) = end of visible motion.

NATURE OF THE MOTION:

i = (impetus) = sudden impulse.

e = (emersio) = gradual development (beginning uncertain).

T = period = time of complete vibration to and fro.

A = amplitude of earth motion—reckoned from the line of rest and measured in microns ($\mu = \frac{1}{1000}$ mm).

E or N attached to a symbol refers it to the E-W or N-S component.

EARTHQUAKE RECORDS FOR 1912.

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS.
					A_E	A_N	
			h. m.	s	μ	μ	
Jan. 4	I	i	16:05.3				S–P=6$^{m.}$ 18$^{sec.}$·Δ=4560km. From data furnished by Graz, Hamburg, Mobile, Ottawa and Saint Louis, φ =68°.6N λ =148°.8 W
		F	18:22				
Jan. 31	II	iP	20:19.5	3	5	4	
		S	20:25.8	T_E = 6 T_N = 6.9	6	5	
		L	20:30.6				
		M_E	20:35	8.4	12		
		M_N	20:35.2	8.4		5	
		C_{1E}	20:42				
		C_{2E}	20:45.1				
		F	21:47				
Mar. 11	Ir	eP	10:27.5				S–P = 3$^{m.}$ 28$^{sec.}$ Δ = 2050km.
		S	10:30.9				
		M_{1E}	10:33.9	10	28		
		M_{1N}	10:33.9	8		23	
		M_{2E}	10:35.8	10 1	32		
		M_{2N}	10:36.1	10.1		67	
		M_{3N}	10:37	7.8		28	
		M_{3E}	10:37.6	8	20		
		F	11:28				
May 6	II	e	19:08.5				The first part of the record is too indefinite to allow of phase analysis.
		$?L_N$	19:15.4				
		$?L_E$	19:15.5				
		M_N	19:27.9	15		126	
		M_E	19:27.9	11	51		
		F	20:21				

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE A_E	A_N	REMARKS
			h. m.	s	μ	μ	
May 23	II	e_E	2:44.9				
		e_N	2:46.5				
		L_E	3:19.9				
		$?L_N$	3:25.7				
		M_E	3:25.2	36	183		
		M_N	3:36.5	28		200	
		F	4:30.				
Jun. 7	I	e_N	10:59.				
		e_E	11:00.				
		F_E	11:09.				
		F_N	11:28.				
Jun. 7	I	e	18:42				
		F	19:08				
Jun. 8	I	e	7:11.9				
		F	7:28				
Jun. 8	IIr	P_N	7:49.9				$(S-P)_E = 6^{m.} 30^{sec.}$
		P_E	7:50.4				$\Delta = 4780$ km.
		S_E	7:56.9				Microseisms during greater
		L_N	8:00.4				part of the day.
		L_E	8:00.6				
		M_E	8:02.9	15	126		
		M_N	8:03.2	15		252	
		F_N	8:34				
		F_E	8:38				
Jun. 8	I	e	9:05.4				
		M_N	9:15.1	12		34	
		M_E	9:15.1	9	9		
		F	9:29.				

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE		REMARKS
					A_E	A_N	
			h. m.	s.	μ	μ	
Jun. 8	I	e_N	13: 15.9				
		e_E	13: 17.7				
		L	13: 23.				
		M_E	13: 25.6	12	31		
		M_N	13: 27.8	13		49	
		F	13: 52.				
Jun. 9	I	e_N	17: 38.8				
		e_E	17: 39.9				
		F	17: 46.				
Jun. 10	IIu	P	16: 14.4				$(S-P)_N = 6^{m}.51^{sec.}$
		S_N	16: 21.2				Δ = 5160 km.
		S_E	16: 21.3				
		L_E	16: 30.6				
		L_N	16: 30.7				
		M_N	16: 34.3	18		163	
		M_E	16: 35.6	15	114		
		F_E	17: 40				
		F_N	17: 41				
Jun. 12	I	e	7: 26.8				
		L_E	7: 31.				
		L_N	7: 31.1				
		M_N	7: 31.1	14		25	
		M_E	7: 31.2	12	16		
		F_E	7: 37.				
		F_N	7: 39.				

DATE	CHARACTER	PHASE	TIME	PERIOD T	AMPLITUDE A_E	A_N	REMARKS.
			h: m.	s.	μ	μ	
Jun. 12	IIr	iP_N	12:48.8				$(S-P)_N = 3^{m.}59^{sec.}$ Δ = 2430km.
		eP_E	12:49.				
		iS_N	12:52.7				
		iS_E	12:52.8				
		L_N	12:53.7				
		L_E	12:53.8				
		M_N	12:53.9	10		108	
		M_E	12:54.1	12	47		
		F	13:33.				
Jun. 18		e_E	12:02.2				Microseisms prevail.
		?e	12:25.7				
			h m s				
Jul. 7	IIIu	P_E	8:04:52				S-P = $5^{m.}53^{sec.}$ Δ = 4175 km.
		P_N	8:05:22				
		P_{RIN}	8:07:08				
		P_{RIE}	8:07:16				Quake in Alaska.
		S_E	8:11:09				
		S_N	8:11:15				
		L_E	8:14:57				
		L_N	8:15				
		M_{E1}	8:20:39	12	1613		
		M_{N1}	8:20:44	12		1366	
		M_{E2}	8:20:50	13	1988		
		M_{N2}	8:20:56	14		1588	
		M_{E3}	8:21:02	12	1388		
		M_{N3}	8:23:28	10		751	
		M_{N4}	8:23:40	11		951	
		F_N	9:47.				
		F_E	10.				

DATE	CHARACTER	PHASE	TIME	PERIOD	AMPLITUDE		REMARKS.
					A_E	A_N	
			h. m. s.	s.	μ	μ	
Jul. 8	IIu	P	22:01:50				S-P = $6^{m.}39^{sec.}$
		S	22:08:29				Δ = 4990 km.
		L	22:14;30				
		M_E	22:17:04	11	183		
		M_{N1}	22:17:04	11		150	
		M_{N2}	22:20:04	11		156	Reported from Alaska.
		F	23:10				
Jul. 21			13:30 to 14:00				
			15:02 to 15:07				
Jul. 22		e_E	9:58				
		e_N	9:58				
		?F	10:06				
Jul. 22	I	e_E	23:49.9				e in local disturbance.
		e_N	23:49.8				
		$?_N$	23:52.9				
Jul. 24	Ir	eP_N	12:07.7				$(S-P)_E = 6^{m.}6^{sec.}$
		eP_E	12:07.8				$(S-P)_N = 6^{m.}13^{sec.}$
		iS_E	12:13.9				Δ= 4340 km.
		iP_N	12:14.				Reported from Guayaquil
		M_E	12:13.9	8	10		Ecuador.
		M_N	12:14.	4		5	
		?L	12:18.				
		F	12:36.				
Jul. 25	I	e_E	23:26.6				Principal disturbance between 0:04 and 0:15. N-S very faint.
		$?_E$	23:36.6				
26		L_E	0:04.7	to 24			

Date.	Character.	Phase.	Time	Period T.	Amplitude.		Remarks.
					A_E	A_N	
			h: m.	s.	μ	μ	
Aug. 6	I	P	21:29.7				Periods very small.
		S	21:36.6				
		?L	21:40.				
		L	21:46.4				
		C_N	22:06.3				
Aug. 9	IIu	$e?_E$	1:39.9				
		e	1:40.5				
		$e?_N$	1:38.7				
		S_E	1:50.9				
		S_N	1:50.9				
		eL_E	2:03.4	56	410		
		eL_N	2:03.5				
		M_E	2:15.7	23	272		
		M_{N1}	2:18.8	18		135	
		M_{N2}	2:15.	20		126	
		F	3:19.7				
Aug. 9	I	$?eL_N$	23:32.5				E-W scarcely anything.
Aug. 17	I	S_E	19:40.8				
		L_E	19:50.6	15			
		L_E	20:29.6	20			
		L_E	20:38.1	16			
		F_E	21:11.				
Aug. 18	IIr	P	21:15.6				S-P = $3^{m.}\ 13^{sec.}$
		S	21:18.8				Δ = 1870 km.
		iL	21:19.3				
		M_{N1}	21:19.5	6		15	Earthquake reported from 400 miles west of Albuquerque, N.M.
		M_{N2}	21:21.	6		10	
		M_E	21:21	8	32		
Aug. 19		F	4.00.0				
Aug. 31		L	23:04.2	15ca.			

Date.	Character.	Phase.	Time.	Period T.	Amplitude.		Remarks.
					A_E	A_N	
			h. m.	s.	μ	μ	
Sep. 1		?S_E	4: 10.6				
		?L_E	4:35.2	6			
Sep. 10	I	e_E	16: 14.7				
		e_N	16: 14.7				
		L_N	16: 16.9				
		L_E	16: 17.				
		M_N	16: 18.6	10		12	
		?F	16:35.				
Sep. 13		L_N	24: 13.4	15-18			
Sep. 20		?P_N	21:30.2				
		?L_N	21:48.9	12			
		?F	22: 17.				
Sep.29	Iu	eP	21: 11.2				Δ = 8370 km
		eS	21:20.8				
		?eL_E	21:42.3				
		?eL_N	21:41.1				
		L_N	21:49.4	32		27	
		L_E	21:48.5	32	67		
		L_N	21:58.1	20		41	
		L_E	21:56.5	20	32		
		F_N	22:47.1				
		F_E	22:49.3				
Oct. 12	I	?eL	15:59.8				
		?F	16:43.5				

Date.	Character.	Phase.	Time	Period T.	Amplitude. A_E	A_N	Remarks.
			h. m. s.	s.	μ	μ	
Oct. 18	I	eP	12:13:42				S-P = $6^{m}.54^{sec.}$
		S	12:20:36				Δ = 5260 km
		eL	12:24:30				
		M_E	12:25:32	16	4		
		M_{N1}	12:25:32	16		5	
		M_{N2}	12:31:10	16		6	
		?F	13:04				
Nov. 7	IIu	eP	7:48.6				S-P = $6^{m}.30^{sec.}$
		eS	7:55.1				Δ = 4830 km.
		eL	7:58.6				
		M_{N1}	8:04.3	11		57	
		M_E	8:04.5	12	43		
		M_{N2}	8:07.5	13		69	
		?F	8:43				
Nov. 7	I	?eP_E	16:05.7				
		?L_E	16:50.8				
		?L_N	16:14.6				
Nov. 7	I	e_N	16:50.3				E-W very slight record.
		eL_N	16:55.3				
		eL_E	16:55.4				
		?F_N	17:19.				
Nov. 7	I	L	17:40.4				
		?F_N	18:13.				

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	A_N	Remarks.
			h. m. s.	s.	μ	μ	
Nov. 19	IIr	iP_N	13:59:41				S-P = $3^{m}.53^{sec}$.
		eP_E	13:59:42				Δ = 2420 km.
		iS_E	14:03;33				Mexico.
		iS_N	14:03:35				
		M_{E1}	14:03:33	10	25		
		M_{N1}	14:03:44	10		127	
		?L	14:04:41				
		M_{E2}	14:09:55	8	20		
		M_{N2}	14:13:27	6		26	
		?F	15:00:00				
Nov. 22	I	?eL_N	1:10:33				Microseisms prevail especially before midnight 21st inst. Quake reported from Vancouver Island B.C. Time determinations uncertain.
		?eL_E	1:10.7				
		?F_E	1:24.				
Dec. 5	Ir	?eP_N	12:35.9				eP in local disturbance.
		?eP_E	12:35.9				S-P = $6^{m}.7^{sec}$.
		eS	12:42.2				Δ = 4430 km.
		eL	12:45.9				
		M_N	12:54.3	18		1mm	
		?C	13:17.2				
		?F_E	13:32.8				
Dec. 5		?eS_N	17:51.1				e in local tremors.
		?eL_E	17:59.6				
		?eL_N	17:59.6				
		?F	18:13				

Date.	Character.	Phase.	Time.	Period T.	Amplitude.		Remarks.
					A_E	A_N	
			h. m. s.	s.	μ	μ	
Dec. 7	I	i	23:05:28				Microseisms make determinations of P and F impossible. No M in L waves.
		iM_E	23:05:28	5	26		
		iM_N	23:09:18	5		26	
		$?L_N$	23:09:18				
		$?L_E$	23:09:25				
Dec. 9	IIr	eP_N	8:37.5				S-P = $4^{m.}11^{sec.}$ Δ = 2580 km. No P on E-W. eL uncertain.
		eS_N	8:41.7				
		eS_E	8:41.8				
		$?L_N$	8:43.3				
		$?L_E$	8:43.1				
		M_{N1}	8:42.2	12		97	
		M_E	8:42.6	8	15		
		M_{N2}	8:51.6	14		85	
		F_N	9:18.8				
		F_E	9:28.5				

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The
Geophysical Observatory

Seismological and Meteorological Departments

UNDER THE DIRECTION OF

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AND

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PART I.

SEISMOLOGY

On the Epicenter Problem.

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1. INTRODUCTORY.

We present herewith two papers on the subject announced. The section headings of the two papers are numbered consecutively, to facilitate reference. The second paper comprises sections 12—14.

At first our ambitions did not soar above the modest purpose indicated in the subtitle of the first paper. We were soon compelled to recognise the gruesomeness of the charts our method was producing. The apologetic tone of our first paper is due to that circumstance. It seemed unnecessary to withdraw the apologies, when the very gruesomeness of the product led to quite unexpected results.

As our work progressed we became more and more convinced that an epicenter could be located with considerable certainty, if three conditions were fulfilled, namely:

1. If the theory of the W & Z curve (Sect. 3) is correct.

2. Supposing the first condition, if data were available, which conformed accurately to that theory.

3. If there were available a not too laborious way of translating such accurate data into curves, of which the roughly sketched curves of our charts may serve as diagrams.

The first condition seems to be generally assumed. Over the second we have no immediate control, but we thought that our idea of Time-Difference Charts might aid in procuring a greater number of reliable records, and thus contribute toward the realisation of the second condition. We encountered a seeming fulfilment of the third condition in the course of our work, and that fulfilment, such as it is, we present in the second paper, on the somewhat doubtful supposition that the scheme is unknown or untried, in seismology at least, since we can find no reference to it in the seismological literature now in our hands.

In consequence we respectfully submit for consideration the claim that Time-Difference Charts, of the species described in our first paper, but computed by one of the methods presented in our second paper from data, representing accurately the theory of the W & Z curve, solves the

Problem: To locate an epicenter; given the correct arrival times of the P tremors at the chart stations.

Of this problem Dr. Geiger wrote in 1910: "Wenn es nun moeglich waere, eine Methode der Herdbestimmung anzugeben, die einzig auf Ankunftszeiten und auf der Laufzeitfunktion der I Vorlaeufer beruht, dann koennte der Herd jedes noch so komplizierten Bebens mit sehr grosser Schaerfe angegeben werden, sobald der Anfang der I Vorlaeufer scharf bekannt ist. Nimmt man wieder an, dass die Ankunftszeiten eine Unsicherheit von ±1 Sekunde enthalten &c."*

We assumed, of course, that the arrival times can be, and are, determined with rather great precision. And then we found that charts, even our rough diagrams, supply a rather searching test of the accuracy of the arrival times, reported by the stations.

The effective formulæ of our second paper may be described as parametric equations of our Time-Difference Loci, and of all sorts of cognate loci. On this fact a second claim may be based, namely:

The method, suggested in our second paper, in connection with even rougher Time-Difference Charts than ours, gives a solution of the

Problem: To locate the epicenter; given the correct S-P of any two stations whatever, and the fairly correct arrival times P for the three stations of a single chart, in very many instances, and in all instances, practically, if a second chart is available, one of whose stations, at least, differs from those of the first chart.

To what extent the accuracy obtainable by the methods suggested, may warrant the labor required, we must leave to others to decide. And that seems to call for a few remarks on the mathematical method. As stated before, we could find no reference to it in our seismological literature, not even in the resume of methods by Dr. Tams, published in 1913.** The formulæ presented themselves so readily, at our very first attempt, that we could scarcely suppose them unknown. That would mean that they had been tried and abandoned as impracticable. Still, the little trial we were able to give the scheme seemed to indicate that it was practical, and the way we happened upon the formulæ might explain why they were not known in seismology.

Our chart making led up to the formulæ. In that process we used the transfer time as the independent variable. Hitherto the

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***Herdbestimmung bei Erdbeben aus den Ankunftszeiten. L. Geiger*, 1910.

***Neuere Fortschritte auf dem Gebiete der Erdbebenforschung.* Dr. E. Tams, 1913.

transfer distance seems to have been used thus. The W & Z curve will give the distance corresponding to a given time, or the time corresponding to a given distance with equal ease (or difficulty). But Dr. Geiger makes use of distance as the independent variable, in all his tables. For this reason, by the by, we could not use his tables directly in our work. If attention had been directed away from the realm we were working, then the formulæ might still be unknown. On this assumption, and to establish, if possible, the rather brave claims we just preferred, we publish our second paper.

In the first section of that paper we deduce the formulæ. If that work should seem rather elementary, we suggest in extenuation that it is also quite brief, and that it seemed the simplest means, whereby we could define both the meaning of the formulæ and the terms they contain.

Much might be said, on general principles, to commend the formulæ.

The manner of deducing them guarantees their accuracy.

The method, on which our second claim is based, is direct.

The result obtained by this method is unequivocal. For the S-P from one pair of stations, one latitude and one longitude is returned for the epicenter.

The work is simple in several senses. After the constants for the pair of stations have been prepared, once for all, the work is entered by means of the cosines of the S-P. After that the work is purely numerical until sine latitude and tangent longitude are obtained.

The formulæ themselves provide unexceptionable guidance for the work.

The obvious objection, that the formulæ are not suitable for logarithmic work, we have tried to meet fairly in the conclusion to the second paper. In the same place we have indicated the real difficulty in the work, with its compensating advantage. The difficulty is that large tables must be used if a high degree of precision is demanded, the advantage, that it is easy to gauge the size of the tables required, for any degrees of precision demanded. And we might add that the nearest minute (arc) of latitude and longitude can be obtained with five place tables, unless the epicenter should happen to be in a very high latitude, or unless the pair of stations should be very close together.

This does not interfere with the original purpose of our charts. Hence we publish our first paper in almost its original form, apologies and all. The purpose of the paper is to explain the idea, which the charts are to illustrate practically; also to explain the manner of constructing the charts in such wise, that anyone interested might be able to construct for himself similar ones for any set or sets of three stations, with the least possible trouble and the greatest possible speed. Hence, wherever it seemed to us that fewer words might make our meaning at all doubtful, we elected to use the greater number of words. But we have tried to omit from the story all that did not serve directly the purposes just indicated.

We also found that the same explanations serve the purposes of our second paper admirably. The first paper being supposed, the second could attend strictly to its proper business, all explanations being disposed of by reference to the pertinent section of the first paper.

The first chart we undertook is the European one, and almost all references in the first paper are to that chart, since our time limit might have precluded publication of the American charts. It does not seem necessary to alter the references.

Our thanks are hereby tendered to Rev. C. J. Borgmeyer, S. J., Professor of Mathematics in St. Louis University, for mathematical work done in connection with this bulletin.

FIRST PAPER.

2. TIME-DIFFERENCE CHARTS.

TO DETERMINE APPROXIMATELY THE EPICENTER OF AN EARTHQUAKE, WHEN THE ARRIVAL TIMES P AT ONE OR MORE SETS OF THREE SELECTED STATIONS ARE KNOWN.

The calculation required to locate an epicenter is not easy. The mathematical methods, with which we have become acquainted, are long, and, for the most part, involved. In the Publications of The Geophysical Observatory of The St. Louis University, for 1911 and 1912, we presented the methods of Prince Galitzin, Dr. Geiger and Dr. Klotz. Before submitting our charts we wish to refer our readers to the methods proposed by Dr. C. Zeissig. Two of these methods he published in Gerland's Beitraege zur Geophysik, XI Band, 2/4 Heft. Dr. Zeissig has used these methods since 1910, and he reported on them at the Manchester Convention in July, 1911*. These methods make the solution of the epicenter problem comparatively simple, but they afford only an approximate location of the point sought.

Both these methods of Dr. Zeissig aim directly at determining the azimuth of the epicenter in relation to some seismic station. This azimuth, and the epicentral distance, (the latter obtained from the

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**Comptes Rendus Des Seances*·····... *De L' Association Internationale de Seismologie.* Manchester, 1911.

S-P in the well known transfer time tables), are then employed to fix the geographical coordinates of the epicenter. The author provides tables, from which these coordinates may be obtained, when the data, azimuth and epicentral distance, are known.

In the first of these methods Dr. Zeissig makes use of the differences of arrival times at two or more stations. These, with the known velocities of the incident longitudinal waves, determine the normals to the several wave fronts. The azimuth of the epicenter, in relation to one of the stations, is obtained from these normals.

In the second method Dr. Zeissig makes use of the epicentral distances, obtained from the S-P of the transfer time tables. The direction angle of the epicenter is then considered as a function of the difference between two station distances of the epicenter, and thus the azimuth of the epicenter is arrived at.

July 1, 1912, Dr. Zeissig sent a third method to the Physikalische Zeitschrift. This method he entitles "Graphische Bestimmung eines Erdbeben Epizentrums aus den Ankunftszeiten P." The article appeared in the Physikalische Zeitschrift, 13 Jahrgang, 1912, p. 767. In this method Dr. Zeissig discards the use of the epicentral distances, obtained from the S-P. Instead he assumes two epicentral distances, one somewhat less, the other somewhat greater, than the probably true one. He calculates the $\Delta_2=\Delta_1+\delta$ from the difference P_2-P_1, (Fig. 1.) Thus he determines the points E and E_1, between which the epicenter will be found. The latter can then be determined by introducing the elements, obtained in a similar manner, from the

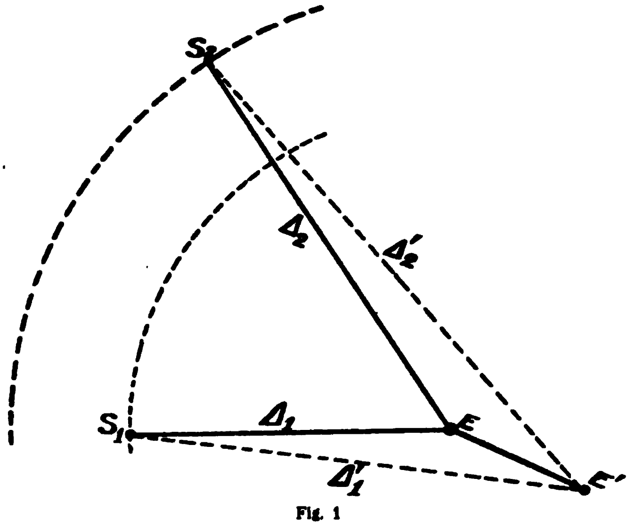

FIG. 1

records of a third station. Dr. Zeissig calls attention to the fact that the three stations should be chosen with a view to obtaining lines, intersecting at right angles, or nearly so. If the stations, chosen or available, do not fulfil this condition, then he recommends one or other of the methods previously published by him.

With all these methods at our disposal we desired something "easier" and "quicker", even if it were lacking a trifle, or so, in accuracy. Perhaps others have cherished similar desires. The methods just referred to, employ, for the most part, the published information about the transfer times of seismic disturbances. This information is published both in tabular form and graphically. The mathematician prefers his data in one of these forms, and his methods alone can locate an epicenter definitively. But it seemed to us that the same data could be presented in a form which would locate an epicenter approximately without the further intervention of any calculation. We present the result in our TIME-DIFFERENCE CHARTS, and we present them with all the apology, which their wildly tangled snakiness may seem to demand.

3. THE W & Z CURVE.

For our experiment we selected the "Laufzeitkurve No. 2" of Wiechert and Zoeppritz, given in Tafel I of their book "Ueber Erdbebenwellen" 2ter Teil, published in 1907. This curve gives transfer times of the preliminary tremors P for epicentral distances up to about 13,000 km. In the following we refer to this curve simply as "The W & Z Curve."

The correctness of the information, condensed in this curve, is called in question. The authors do not claim that it is correct. The best way to test its accuracy is to apply its data as often and as extensively as possible. An easier way of locating epicenters, even approximately, may secure a larger number of reliable records, and thus help to secure more reliable data.

We were less concerned with the accuracy of the information than with the form of its presentation. Should the form we had devised commend itself (on explanation), then means might be devised to present these, or any more accurate data, in a similar form, to any degree of exactness and of minuteness of detail that might seem desirable.

The explanation of such seemingly lawless tangles of lines has difficulties of its own. Telling the story of the genesis of one of them seems to be about the only possible explanation, which offers any prospect of success. This will also enable anyone interested, to construct for himself similar tangles for any other set or sets of three stations, which he may find serviceable—his own included, of course. The labor will not be very great.

We claim very little that is new in our scheme. The numerical data are public property. In charting them we employed only the simplest geometrical principles. Even this geometrical treatment of the data has not only been suggested, but has been actually employed in locating epicenters. To the best of our knowledge, the actual charting of the data on these principles has not been presented hitherto, though even this is in line with suggestions contained in our previous Publications. The idea of some such chart must have presented itself to many a one before, perhaps only to be dismissed for its seeming difficulties, or for other reasons, and, for all we know, such dismissal may have been the more prudent course.

4. IDEAS INVOLVED IN THE CONSTRUCTION OF OUR CHART.

According to the W & Z curve, the preliminary tremors of a seismic disturbance will travel 390 km in 1 minute, 855 km in 2 minutes, and so on. Suppose a list made of all whole minute transfer times with the corresponding distances, which can be read from the W & Z curve. Then suppose the following operations:

On a terrestrial globe locate a seismograph station, H (Hamburg) in its exact latitude and longitude. Open a pair of dividers to span the 1 minute distance (an arc representing 390 km on the globe). Place the pivot leg of the dividers on the station, H, and with the marking leg draw the small circle, with 1 minute transfer distance about H as a pole. Call that circle H_1. In like manner draw H_2, with H-polar distance equal to 2 minutes of transfer-time distance. Continue thus to the end of the distance list, say to circle H_{15}.

Select anyone of the circles, say H_n. Then, from any point on H_n, the preliminary tremors P of an earthquake would pass to the instrument at H in just n minutes of time, i.e. in as many minutes as there are units in the subscript of the symbol of the circle selected. Such a set of circles, if drawn, would cover distinctly more than half the surface of the sphere, and, an earthquake, recorded on the instrument at H, would have its epicenter somewhere within that area, unless the epicenter should be so far from H, that its location could not be attempted by means of the W & Z curve, as we have it. More than this cannot be claimed for such a set of circles, so long as nothing further is provided.

Now select another seismograph station, V (Vienna), which, on earth, is at a serviceable distance from H. We are not prepared to define this "serviceable distance." It may be that close stations are better in the case of epicenters at small distances, distant stations, better in the case of distant epicenters. But small distances are apt to crowd the lines in some regions of the chart, distances greater than would correspond to 6 or 7 minutes of transfer time, reduce the area of the chart. Suppose the station V selected, located on the same globe, and surrounded by a set of circles, V_1, V_2, and so on, similar to the set of H circles. The letter, then, will indicate the set, to which any circle belongs, and the subscript the transfer time in minutes from a point on the circumference to the station, which names the circle.

Unless the stations are very far apart, the two sets of circles will intersect in numerous points. We must now classify these intersections. H_1 will not cut V_1, as a matter of fact. Should these circles cut each other in any other set, then the stations are rather too close together. But, moving outward from H a circle, H_n, will soon be found, which is tangent to, or which intersects a circle of the V set, with the same subscript, V_n. Mark these intersections. Every circle of the H set, with subscript greater than n, say H_{n+m} will then intersect the circle of the V set with the same subscript, V_{n+m}. Mark all such intersections. Each of the points, so determined is as far from H as from V. A uniform curve, drawn through all these points will be a large part of the great circle, which perpendicularly bisects the arc HV. Every point on this great circle is as far from H as from V, and, conversely, all such equidistant points are on that great circle. Hence, a tremor, recorded simultaneously at H and V can come only from some point on this great circle. Call this locus: H—V=0.

The next intersections to be looked for are those of circles of the two sets, whose subscripts differ by unity. Some circle, say H_n, will touch or intersect V_{n+1}. Every circle of the H set with subscript larger than n, say H_m, will then cut the V circle, with the next larger subscript, namely V_{m+1}, in two points, until a certain upper limit is reached, which is discussed in Sect. 7. Third. A uniform curve, drawn through all the intersections just specified, would be the locus of all the points, which, as epicenters, would send P tremors to H and V, that would record themselves at H just one minute sooner than at V. Call the locus: V—H=1 minute.

Drawing a similar curve through all the intersections of V circles, V_m, with circles H_{m+1}, would give a locus: H—V=1 minute. A P-tremor from an epicenter anywhere on this locus would reach H just one minute after recording its arrival at V.

Similarly, intersections of circles of H_n with circles V_{n+2}, and of circles V_n with circles H_{n+2}, would give respectively the loci: H—V=2, and V—H=2. In like manner, loci H—V=3, 4, 5 and so on minutes, and V—H=3, 4, 5 and so on, minutes should be drawn until the limit of the intersections is reached, which will be very soon if the stations are close together. In the case of the VH set the greatest possible difference in whole minutes is 2, and that 2 minute locus is a very small affair.

Suppose all such loci drawn on the globe, and then suppose that P-tremors from an earthquake are recorded at H just r minutes sooner than at V, then the epicenter must be on the locus V—H=r minutes, if such a locus is possible. Also, if r is an integer and within the proper limit as to size, then the locus will be found on the globe, and some point, of the line actually drawn will be the epicenter.

But the locus V—H=r may sprawl widely over the globe. It will sprawl most surprisingly, if r is small and the stations close together. Hence we would still be far from even an approximate location of the epicenter. We would have gained merely this, that in our search for the epicenter we could confine our attention to a single line, instead of having to worry over the entire surface of the globe.

The epicenter may be located more definitely by calling in the aid of a third station P (Pulkowa), which should be at serviceable distances from both H and V. Suppose such a station selected, located on the same globe, surrounded by its set of circles P_1, P_2 and so on, and also suppose drawn the loci H—P=0, 1, 2, and so on and the loci P—H=1, 2 and so on. If now it should be found, that the epicenter, which we just located on the V—H=r locus, recorded itself at P just s minutes sooner than at H, then the epicenter would also be on the locus H—P=s minutes. These two loci should, therefore intersect, and evidently some one of the intersections must be the epicenter.

In planning our charts we had calculated on two intersections at most—but the only statement we can now venture is that the intersections come in pairs, and that there will not be many pairs of them, if the loci intersect at all. This would reduce the problem to deciding which one of a comparatively few points is the epicentral point. In some instances the selection can be made by means of the data furnished by a single chart. In most instances by the data just referred to together with some S-P value, which need not be very accurate either. In all instances, practically, the selection is determined by the data of a second chart, one of whose stations, at least, differs from the stations of the first chart. (Some one will suggest that there are no "epicentral points". Well, to be precise we must deal with "points". A little widening, in practice, will take care of the "areas".)

The P-circles intersect the V-circles also. Hence we can also draw the loci V—P=0, 1, 2, and so on, and P—V=1, 2, and so on. Should we then find that the same tremors were recorded t minutes earlier at V than at P, then the epicenter must also be on the locus P—V=t. This third locus will pass through all of the intersections of the other two loci. The epicenter will be one of these intersections —if the W & Z curve is correct in all respects, and if it is charted correctly, and if the three arrival times are recorded and then read correctly, and if the first preliminary tremors met with no accidents on the way, and any other ifs, which do not occur to us just now.

Some one may think that this third set of loci cumbers the wild chart with a great deal of additional confusion, and to very little purpose. Its service is not as trifling as it seems to be.

It will be found that the VP locus, after condescending to the other two in the slight matter just mentioned, as a rule pursues a quite independent course over quite distinct areas of the chart. This alone might indicate that it can serve purposes of its own. It seems that some of these purposes should be indicated here.

1. At best only a few of the loci of any three-station set can be drawn on a chart. Hence an epicenter will be found but rarely on a locus actually drawn. And therefore to locate the epicenter we must have recourse to interpolation in most instances. This process will be both more easy and more reliable, the nearer an epicenter is to some locus on the chart. Drawing the third set of loci will increase by about 50 per cent the chances that some locus of one of the sets may pass near the epicenter.
2. As we shall show in Sect. 7, the loci of each set define areas within which the epicenter must lie, if the arrival times are recorded correctly at the two stations, which name the locus.
3. In Sect. 9 we show that this third set of loci gives most welcome, visible evidence of the wholly unexpected accuracy of our "easy" charting method.
4. That the third set enables us in some cases to locate the epicenter with considerable precision, by means of a single chart, we shall illustrate in Sect. 11. That the same set supplies a very searching test to the consistency of the arrival times, reported by the three chart stations, we shall indicate more precisely in Sect. 10. We are not prepared to state the lower limit of such inconsistency that can be thus detected, but we shall illustrate in Sect. 11 that the chart does rule out peremptorily some sets of data, which look quite proper as presented.

5. FROM THESE IDEAS TO THE CHART.

We are evidently placing a heavy burden on the accuracy of a chart, drawn as described in the preceding section. For us this difficulty had been solved by a previous venture. Our first plan was to produce our Berkeley-St. Louis-Ottawa chart, on a large scale and with all the precision obtainable. Just that, and nothing more. (Publication to be dependent on circumstances.) For this purpose a sufficient number of points had to be determined somehow, but with such accuracy, that the loci, drawn to their guidance, would realise our intentions, or nearly so.

The only safe way to make these determinations seemed to be the solution, for each point, of the terrible series of triangles, whereby every text of elementary Spherical Trigonometry solves problems of the kind. Such a gigantic task could be justified only by some very good evidence that the result would prove eminently useful. Prof. F. W. L. Peebles, E. E., faced the task for us, and computed points for a rather small portion of the intended chart.

We had a 12 inch (305 mm) spherical blackboard handy, and this suggested the circle method, detailed in the preceding section. On this globe we drew the first five or six circles of each of the B, S and O sets, and sketched in the loci, in the manner just detailed. The results of this venture agreed so remarkably well with the calculated data, that we promptly concluded to eliminate all calculation, and construct the entire chart by the "easy" method, found so opportunely. We also concluded that this graphic way would not give the accurate result which we had intended, but it would supply an extended working model, which might determine whether resumption of the abandoned calculation would be justifiable.

Although our "easy" method was thus developed on a globe, a globe chart was undesirable for a number of reasons. Since every chart of the kind covers a good deal more than half the globe, every new three-station chart would require a new globe. Now, not to dwell on volumetric considerations, a new paper chart is apt to be less expensive than a new globe. Again, a flat, well-behaved chart is ever so much easier to study than a globe, fidgeting on a pivot. A globe area, moreover, is strictly limited in size, a paper chart can be expanded ad libitum. Finally, and especially, we wanted to publish our idea, diagram and all, for criticism, approving or otherwise, and a globe cannot be published conveniently.

So the points, determined on the globe had to be transferred to the chart. But even the work on the globe had its difficulties. Even the few circles we actually drew on the globe formed a perfect wilderness of intersections. Yet at least forty-five circles to each set would be required to secure loci for every twenty seconds of transfer time difference. To that limit the W & Z curve can be read with comparative ease. Worse still, even the outermost circles of our very limited collection showed quite indeterminable interesctions, as a matter of course. We avoided all these difficulties by drawing no circles at all, when we took the chart in hand.

For reasons of no interest now, we passed to the other Continent for a first trial, and selected the trio of stations, Hamburg, Vienna and Pulkowa, which supplied the capital letters of the preceding section. One inconvenience, which arises from the proximity of H to V, is that the loci are crowded together about the longitudes 80° and 280°. But with the three charts, which we are now able to present, we illustrate effects of varying distance and varying position in considerable variety, and that may make judicious selections of chart stations possible.

To determine points for the loci we procured an 18 inch (458mm) terrestrial globe. It rotates on an iron pivot, which pierces the shell in the polar regions, has an equator, divided into single degrees of longitude, and has parallels of latitude drawn for every 10°. We compared the positions of H, V and P on the map, with the latitudes and longitudes of the respective Observatories given in the Bulletin of the British Association*, and concluded that the map located the stations about as accurately as we could. At each of the stations a pinhole was bored right through the papier mache shell of the globe.

After trying various materials we finally procured narrow strips of thin spring brass. Ours are about 7mm wide. A line was drawn down the middle of two of these strips, and a pinhole pierced near one end of each strip, the center of the pinhole being on this line. Along the mid-line of each strip were laid off, and marked clearly, distances from the middle of the pinhole, corresponding to epicenter distances (as represented on our globe) requiring 20 seconds, 40 seconds and so forth of transfer time, up to the limit of the W & Z curve. Pinholes were then pierced through each strip, at the intersections of the mid-line with each mark. These distances we read from the W & Z curve, estimating to the nearest hundredth of a megameter. We accommodated these distances to our globe by means of the relation: 1 megameter equals 9° of a great circle. To determine the length in mm of 1° on the globe, three great circles were measured with a mm tape line, namely, the equator, a meridian and the inevitable ecliptic. Dividing each of these measures by 360, gave us three values of the great circle degree. We took the mean of the three values, and made no further investigation of the peculiar sphericity of our globe.

The end pinhole of one of the strips was then placed over the hole pierced at H, and an ordinary pin inserted, to serve as pivot. The other strip was similarly pivoted at P. The papier mache endured the consequent abuse remarkably well. The pivot pins were gripped

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firmly even after numerous insertions and removals. These details are trivial, but, had we known them to begin with, we would have been saved a good deal of time and trouble.

We could now mark on the globe a large number of points, belonging to loci of the HP group. To mark points on the locus H—P=0 (the great circle, which perpendicularly bisects the arc HP), the pinhole at 2 minutes of transfer time distance on the H-strip was placed over the 2 minute hole on the P-strip, a pin inserted, and the rigid triangle, so determined, laid on the globe surface. A (not indelible) mark was made at the point indicated. Similarly, marks were made by means of the 3 minute, 4 minute and so on pinholes, to the end of the graduation. Then the strips were swung around to the other side of the HP arc, and the part of the bisecting great circle marked out on that side.

To mark points on the locus H—P=1 minute, the mark at 3 minutes from H was matched with the mark at 2 minutes from P, the mark at 4 minutes from H with that at 3 minutes from P, and so on and points marked on both sides of the HP arc. This should suffice to indicate the method followed. We certainly found a very easy and rapid way of locating points for our intended chart. On the accuracy of the resulting chart we shall comment in Sect. 9.

But to transfer the points so determined from globe to chart, the location of the points in terms of latitude and longitude had to be determined. Another brass strip served this purpose. Its length is about 150° of our globe. It was pivoted (removably) at the pole in such wise that one edge of the strip, produced, would pass through the center of the pivot hole. This edge was graduated to degrees, to suit our globe, and the graduation numbered each way from the equator. The location of the previously marked points is then quite simple. The meridian strip is pivoted, and its meridian edge is placed through the point to be determined. The same meridian edge of the strip then marks off on the equator (divided into degrees) the longitude of the point, and, after that has been recorded, the latitude is read directly from the strip. It will be news to few that greater uncertainty attaches to this determination of the longitude than to any other step in the process.

6. THE CHARTING.

To chart the points so determined, a convenient set of coordinates had to be selected. The entire loci, belonging to any three-station set, cover an area, which involves at least one of the poles. An attempt to plot such loci to rectangular coordinates leads to unmanageable distortion near the pole, the pole itself develops into a straight line, stretching across the entire width of the chart, and it is very difficult to trace any locus from its deformed ending on one side of the pole, into its deformed continuance on the other side. Of course, if the set of three stations is near the equator, both the poles will be involved in the area, and then simple squared paper would seem to furnish the most convenient coordinates. The polar distortion will occur, as a matter of course, but it will affect only the fag-ends of some loci, and they may be useless anyway.

Our stations are not equatorial, and so we selected a simple set of polar coordinates, radiating from the pole involved in the area. We drew them ourselves, to suit our special purposes. Straight lines, intersecting at the pole, are the meridians. Circles, with the pole as center, and spaced equal distances apart figure as parallels of latitude. The longitude numbering adopted has its zero on the Greenwich meridian, and increases eastward, continuously, to 360°. This is analogous to the R. A. numbering in astronomy. The continuous numbering is by all means the more convenient, and carrying the numbers the other way about introduces difficulties.

Since we are not much concerned with area on the chart, but only, or chiefly, with latitudes and longitudes, such a set of coordinates seems admissible. Beyond the equator things acquire an unfamiliar look, but the meridians and circles provide all needed guidance even in that region.

It might be well to call attention to one other little practical trifle. The pole of the earth must, of course, remain the pole of coordinates too, but the station triangle is, of necessity, the center of the chart. Hence, if the coordinate lines are drawn with the pole in the center of the paper, and if a generous scale of latitude is then adopted, a chart for a low latitude station set might find itself mostly off the paper. The full size of the drawing paper may be best utilised by reserving the center of the paper for what might be called the center of gravity of the station triangle. Proceed as follows. Mark the center of the paper. Subtract one-third the sum of the latitudes of the stations from 90°. Select some point at this complementary distance from the center of the paper, to serve as pole. Draw the coordinate lines with reference to the pole point so selected. Then the longitude numbering must begin on the meridian, which passes nearest the center of the paper. Assign to that meridian the nearest 5° or 10° to the number obtained by dividing the sum of the longitudes of the stations by 3. Then continue the longitude numbering eastward.

Beyond this, the plotting of the loci should need no remarks. After the points have all been plotted for any one locus, the locus is drawn (as usual in such cases) to form "a uniform curve, best satisfying the position of the points". A glance at our charts may suggest the idea that "uniformity" has a peculiar meaning with us.

But all our loci were not drawn in this manner. On the European chart all the loci for 0, 1 and 2 minute differences were so plotted, also the H-V loci for 20 and 40 second differences—and two more loci. After plotting the V—P=0, and V—P=1 minute loci, it occurred to us to fill the gaping void between them, by plotting in the 20 and 40 seconds difference loci, which belong there. But another very definite purpose of this proceeding was to test the reliability of our method. We plotted both these loci, in both directions from the VP line, only omitting the parts within and near the station triangle, since that area was showing signs of overcrowding even then. As may be seen the loci fairly trisect the area between the 0 and 1 minute loci. This is done so definitely that we could evidently have plotted in the loci for the remaining 10 seconds difference loci, without any of the lines fouling each other.

Since we were professedly in quest of "the easy" we promptly took a hint from this experience. All other similarly situated loci (when drawn at all) were just sketched in very simply. To illustrate the process let us take the area between the P—H=1, and P—H=2 minute difference loci. The pivot leg of the dividers is set on H (on the chart). H is the nearer station. The marking leg is then spread until it reaches into a region where there seems to be room for more lines. Swing a light, leadpencil arc from the 2 minute to the 1 minute locus. Draw other such arcs at increasing distances from H, wherever they may seem convenient or useful—until the 2 minute locus tumbles towards its closing point. Trisect each of these pencilled arcs after this manner. Estimate a third of the arc in hand. Spread the dividers to that extent. Test the "guess" by "stepping off" on the arc. Correct, and then mark the two points of trisection. "Uniform" curves drawn to the guidance of these two sets of points will represent the 20 and 40 seconds difference loci, belonging to that space, about as well as the same loci could be plotted from the globe, and they will cost distinctly less labor. Both the loci, so constructed, may be continued for some distance into the void beyond, in the general direction hinted at by the last few trisection points, and the course of the curve with the smaller time difference. Hence the 20 seconds locus can be produced further than the other—but this proceeding can be easily overdone.

This work is not accurate. Certainly not. But it is more correct than a mere eye estimate would be. Furthermore, as indicated at the close of the second paper, a really reliable method of interpolation may be derived from this method, for loci calculated with all precision desirable.

Our delirious charts were constant reminders, in the course of their growth, that it would be a very difficult matter to follow the course of any individual locus, in an attempt to locate an epicenter. Hence, in the first place, we adopted the simple device of inking one of the sets as continuous lines, the other two in short and long dashes, respectively. Perhaps a color scheme would be better, if a detailed and accurate chart should ever be produced. At the same time we kept in view the diagrammatic character we attribute to the charts presented. Hence we introduced as few of the loci as would be consistent with the idea of a working diagram. Our two American charts interlock very thoroughly over the entire region of North and Central America, and almost the whole of South America. The NSO chart interlocks very thoroughly with the European chart over almost the whole of the Atlantic basin, and, to a slightly less extent over the two Americas and Europe as well. The recorded arrival times of tremors from epicenters situated within this very large area of the earth's surface can be tested by means of these diagrams—or the diagrams can be tested by means of these tremors. No very elaborate interpolation will be required for that purpose, but the results should decide as to the value, or otherwise, of our device either for the original purpose we had in view, or for numerous other purposes, suggested by the completed diagrams and their by-products. If we had been able to carry out our plan of a second European chart, combining either Stonyhurst or Shide with either Hamburg and Vienna or Pulkowa and Vienna, the combination of the diagrams would have been still more effective. But it is not for us to make and evaluate the tests. Should anyone be sufficiently interested in the matter to institute some tests of the kind, then he may find a few sample locations of epicenters in the last section of this first paper. Meanwhile we shall try to indicate a few of the "by-products" developed in the production of the charts.

7. CHARACTERS OF THE LOCI.

Some characteristics of our loci are due to the simple geometric basis of our scheme, others are due to the brusk way, in which we reduced the earth's surface to a plane, the rest, and, in particular the "kinks" derive from the W & Z curve. We bargained for all the distortion consequent on our unlawful projection, and have no further comment to offer on that matter. The "kinks" we reserve for the next section. The geometric peculiarities are due to just elementary geometry. In the present section we shall offer some remarks on them, just to call attention to the salient points visualised in the charts.

First. Every point on any one of our loci represents the vertex of a spherical triangle, whose base is the distance between the two stations, which name the locus, and whose sides differ by a length, varying from point to point, but determined in each case by the condition that the transfer time from that point to the more distant station shall exceed the transfer time to the nearer station by the constant time difference, which specifies the locus. This description applies to the zero loci only if the fact that they are limiting cases is remembered.

For further illustration we shall remark on the VP loci. For any point, X, on the locus V—P=0, the triangle VPX is isosceles. For any locus V—P greater than zero, the side VX exceeds the side PX. Hence all such loci lie entirely on the Pulkowa side of the 0 locus. Similarly, every locus P—V greater than 0, lies wholly on the Vienna side of the same 0 locus.

Second. Through any two stations, say V and P, we can pass one and only one great circle. This circle is not shown on our charts, because tremors from different points on that circle would not have the same differences of arrival times at the two stations. For other purposes, even for the construction of the charts, it might be convenient to draw this circle, but another graphic method would be required for that. The method required is given in the geometry of the sphere.

With respect to this great circle all PV loci are disposed symmetrically (on the globe, not on our charts). Because, for any triangle VPX, with its vertex X on the north pole side of this greater circle, there is another triangle VPX′, symmetrical to the former triangle, and therefore with its vertex on the other side of the same great circle.

Third. All the loci are closed curves, and each encloses one of the base stations. Also, in any locus, the point nearest to, and the point furthest from, the enclosed station is on the great circle through the stations. These assertions derive from the simple principle that in any triangle the sum of two sides cannot be less, nor the difference of two sides greater, than the third side. For illustration let us consider a locus V—P=d. Let a circle with V as pole begin with zero radius. (For the sake of brevity we use radius here instead of V-polar distance). Let this circle grow continuously by increasing its radius continuously, the increase per second of time being the corresponding increase of transfer distance according to the W & Z curve. This radius will soon reach a value, such that a tremor from its endpoint would require d seconds to reach V. Just when this change again approaches a somewhat uniformly increasing rate. These conditions could produce no effect on the bisecting great circle, nor on the initial points of the 1 minute difference loci. But when the 5 minute mark on the H strip was matched with the 6 minute mark on the P strip, there resulted a triangle, whose side PX had increased abnormally as compared to the side HX. Hence the vertex was thrown very notably in the direction away from P. In the case of the 6 and 7 minute match, the HX side of the triangle had received one abnormal increase, but the corresponding side PX boasted two such increases, hence the vertex kept its H-ward inclination. After this these increases tone down their effects slowly, and lead to the well behaved outer reaches of the loci. When we plotted the points corresponding to the 20 seconds and 40 seconds increases between the uniform curve and the first of the outstanding points, the additional points marked out a very neat curve "kinking" the regular curve over to the displaced point, and, in the same manner we could "kink" back into the regular curve further out.

The 3-minute-difference curves, which were drawn, did not show the kinks. Neither do they appear in the HV 2-minute-difference curves. All these lie on the station side of the region where trouble is due. In the HV and PV 2-minute-difference curves the kinks appear, but are mostly obliterated by the swing toward the closing point, which begins almost at the trouble point.

This closing swing, by the by, has to be drawn with very little assistance from the measuring strips. Almost the whole of the swing, in the case of these close stations, lies within a single 20 seconds transfer distance, and the actual closing point has to be estimated with very little to base the estimate on. Of course, the point lies beyond the mark (from either station) which was matched with a mark from the other station for the last determinable point—also, the closing point lies nearer either station than the next 20 seconds marks. In our American charts the parts of the loci between the two points last determined on either side, has been omitted for the present. The part of the locus drawn, indicates the form of the closing part so clearly that this may be readily drawn in. Meanwhile the matter is not a very serious one. If the closing point should be jotted down almost anywhere between the limits of its position, which are easily determinable, it would not be far out of place. In the early part of the W & Z curve the 20 seconds differences amount to about 1°, and toward the very end of the old curve they do not reach 4° in length.

For the intermediate loci this kinking matter gets to be far more tangled. To locate points on these loci graphically, 20-second, or 40-second difference marks have to be matched with whole minute marks—or with each other, if all available points are to be determined, as was done for most of our plotted loci. The unequal minute increments are unequally distributed among the subdivisions. The consequences may be appreciated from the snakiness of the resulting loci. But even these extravagances scarcely do justice to the subject when all available points are plotted for a 20-seconds, or 40-seconds difference locus, which depends on a small base besides. For instance, the HV loci for these differences had to be plotted in, if we were to show any HV locus in the vast space between the small 1-minute-difference ovals, and the majestic sweep of the bisector. All the points for these loci were plotted and then connected serially by faint leadpencil lines, preparatory to a generous "smoothing" process. The result looked like an exaggerated instance of the conventional picture of "jagged lightning".

And of course the next question is: what business had we to do any "smoothing"? There were two good reasons for such smoothing as was done. First, we wished to make it possible to follow our loci across the chart, and since it was permissible, we indulged our preference. Secondly, it was permissible since these wild oscillations are certainly exaggerations, and, so far, we have no means to estimate the extent of the exaggeration. For this second reason, especially, the smoothing process was conducted with all convenient deference to the dancing set of points, but more respect was paid to the probalities. Of course, if one or more points persisted in a peculiarly outrageous situation, the curve was adapted to suit their peculiar humor.

The cause of these exaggerations is obvious enough, though we have no means at present to gauge their extent.

The basic cause of all pronounced irregularity in the loci, is of course, the varying rate of the W & Z curve. That irregularity is part of the truth we undertook to represent, and should be maintained as far as it is known.

But our reading of the curve introduced a factor of a different order. We endeavored to estimate the distance to the nearest tenth of the coordinate division of the W & Z chart at our disposal, i. e. to the nearest hundredth of a megameter. We do not claim that we secured the nearest hundredths. One hundredth megameter is 10 km. If in our readings we estimated one distance short by even 10 km, and another distance too long by the same amount, then, if two such marks are matched in locating a point, that point will be swung vigorously over to the "short" side, especially when the base line is short.

As stated in the introduction, we could not use Dr. Geiger's interpolation directly, but we compared our readings with his tables, and the agreement was quite satisfactory with the first interpolation throughout. Our readings agreed even better with the second interpolation (of 1912), up to a transfer time of about 520 seconds, or a distance of 46°. In the succeeding stretch Dr. Geiger used a slightly steeper curve for the second table, and so the transfer times for the same distances increase up to a distance of 69°, for which distance the transfer time exceeds that of the old table by 14 seconds. This maximum differences is maintained to distance 73°. After that the new values approach the old ones to the end of the new table at distance 82°, for which the time exceeds that of the old table by only 6 seconds.

Our charts were to serve as diagrams, hence we wished to make them as extensive as the W & Z curve permitted. The terminal portions of that curve are not considered in Dr. Geiger's new table, nor does the latter connect up with them. Hence we adhered to our readings. This we could do the more readily since loci, plotted to Dr. Geiger's new readings would not differ to any serious extent from those we present. In the part of the curve affected by the new table, each point would be moved toward the stations by an amount corresponding to the change, but the displacement sideways would amount to very little.

Since we could not determine the distances more precisely we had to use the values as we had them. Calculation is no remedy, for only the same defective readings can be fed into the calculation. If an equation of the curve could be produced, or if there were available a set of values adjusted to each other by the masters in this realm, then a chart could be produced—not without kinks, to be sure, but with every kink in its proper place and of the proper size, and no impromptu affairs to add to the natural spiciness of the chart.

A seemingly more serious difficulty is inherent in the graphic method itself, and its effects must become more and more pronounced the closer the stations are to each other, and the further the plotted loci extend from their stations. If the station holes are not bored so that their centers coincide exactly with the geographical position of the stations in question, then the base line of the system of triangles, which depends on these station holes, may be a little too short or a little too long—also it may get a slight tilt out of its proper direction. The actual line determined by the holes, will not differ much in either respect from the line it is to represent, but the vertex of a triangle on such a base, and with sides stretching out to 10 or 12 thousand km will be at quite different distances from the base, according as the latter has its true value, or has been taken too long or too short. A slight tilt of the base might also seem able to give a notable jolt to a vertex at such distances.

And now we have said about all the bad things of our loci that we could think of. We had good reason to think of them. The wild tangle of lines on the charts seemed to be necessities of the case.

We could remedy neither their lawless courses nor their crowding here and there. But if the entire show was out of its proper position, that was quite another matter. We had no desire to publish a seeming nightmare without some tangible assurance that it was more than just the figment of a dream and of a very troubled dream at that. We never lost sight of these possibilities throughout our work, and our digressions referring to tests by the way were intended to reassure any reader kind enough to examine the work. But the appearance of our product, when near completion, seemed to demand more searching tests.

9. ACCURACY OF THE CHARTS.

We refer only to the accuracy, with which the charts represent the data of the W & Z curve employed. A host of triple intersections gave welcome evidence of the consistency of the work, and this evidence we shall specify a little more at the end of this section. To determine whether the loci were of the proper size and in their proper places, at least approximately, a mathematical test offered the only recourse. The old trigonometric way was not inviting, and so we went in search of another way. This we found so soon and so easily that we certainly cannot guarantee its novelty, but, such as it, we present it in the second paper.

This seems to be the proper place to give a few practical data about this mathematical scheme. Since we also propose it as a method for computing points for our kind of loci, we gave it a time and space trial. A tabulation of the work was devised, and after the data had been entered, we did the work required to determine the latitudes and longitudes of over fifty points on one of our loci. We used five place logarithms, but worked only to the nearest fourth place of the numerical values. The area of paper covered measures 61 by 40 cm, but the long dimension includes the width of two colums of tabulation text. The space occupied by determining the latitudes and longitudes of a pair of points measures 40 cm by 19mm. A single point requires about 30 cm by 19 mm. The time consumed in covering the 61 by 40 area was about four hours.

This time requirement is a very generous upper limit. The use of more extensive tables would widen the columns proportionately, but would not increase the time proportionately, and, an expert computer would also shorten the columns.

Incidentally this trial was to give some evidence about the particularly wild V—H=40 seconds locus. Three-fourths of our points measured up into comforting nearness to that deformed cripple. The other fourth failed to make connection, because they belonged to the neighborhood of the pole, and the extent of our numerical basis was too slight to determine points in that high latitude.

A previous trial, undertaken for the purpose of getting the tabulation into manageable shape, was carried out on the HP bisecting circle. All the points (20 seconds intervals) were taken to the limit of the paper employed. The most distant points reached were at 6 minutes transfer time distances from the two stations. Every one of the 26 or 28 locations obtained fitted squarely on the locus, though the same tables mentioned above were employed.

A still earlier trial, instituted for the special purpose of testing position and shape of H—P=1 minute, gave an even more reassuring result. In that trial the nearest fifth place of the numerical values was aimed at. Distances from the stations were selected almost at random, and the results of the computation were compared with the locus, already drawn in ink on the chart. The following table gives the computed latitudes and longitudes, on the north and south branches respectively of this locus, under the pertinent transfer times to Hamburg.

Transfer time to H.		460s	480s	500s	720s	780 seconds
North Branch	Lat.	88°	86°	84°	46.5°	37°
North Branch	Long.	145°	171.5°	168°	171.75°	167°
South Branch	Lat.	33.5°	31°	30.5°	8.5°	3.75°
South Branch	Long.	56°	58°	61.25°	89.75°	101.75°

The locus is on our European chart, and the coordinates may be compared with it. Only two of the points fail to register closely with the locus as drawn, namely the point in Lat. 88° and one of the last two points on the south branch. The numerical values employed in this work could not give a definite location so near the pole, and even the nice fit of the point at Lat. 86° may be more or less accidental. The failure on the south branch may be due to a miscalculation, but it is more likely that an outstanding point did not get sufficient consideration in drawing the locus in this neighborhood. The three sets of results seem to give a satisfactory reply to the suspicions frequently expressed in these pages as to the reliability of the method of plotting we employed.

And now we must attempt a short discussion of our formulæ from another point of view. In Sect. 4 we stated that, if two of our loci intersected they would do so in pairs of points, and then some locus of the third set would pass through all these points of intersection. This may not be self evident, and a thoroughgoing discussion of the matter is too complex an undertaking, so long as the prospects of our scheme are so doubtful. Something in that direction must be undertaken, if an intelligible account of our charts is to be presented.

Our formulæ are derived from the equations of two cones, namely (4) and (6) of Sect. 12. An equation of similar form will give the cone about a third station. Our formulæ are derived from (4) and (6) by using those equations as simultaneous equations. The same equations can be so used in another way, and will then give an equation of the WE loci, having the general form:

$$Auv+Bu+Cv+D=0$$

In this equation u is the sine of the latitude and v the tangent of the longitude of the tracing point. A and B are constants for the stations selected. C and D are functions of the distances of the tracing point from the same two stations.

Let Q be the third station. Then combining the cone about Q, first with (4) and then with (6) will give the equations of the loci QW and QE respectively, and each will be of exactly the same form as the one given above. Anyone of these three equations can, of course, be derived from the other two. Hence, any solution, derived from any two of them must be a similar solution of the third. It would be impossible to plot the loci from these equations, because each of them contains four variables. The same fact explains why an equation of so pronounced a hyperbolic form does not plot as a hyperbola.

If we disregard, for the moment, the variable distances involved in the coefficients, symbolised by C and D, then each of the equations involves only two variables, namely the latitude and longitude of the point which traces the locus. Select one locus from each of two of these sets, but so situated that they will intersect. This involves the condition that only such variable distances shall enter the coefficients C and D, as are determined by points on the particular loci selected. Solving these two equations, so modified, as simultaneous equations, must give us the latitudes and longitudes of their points of intersection. This can be done most readily by solving each equation for u, and equating the values of u so obtained. The result is an equation of the second degree in v. Under the stringent conditions of the problem each of these values of v can refer only to the longitude of a single point. Hence, so far it would seem that the two loci can intersect in but two points, since a single longitude value means a single value of the corresponding latitude.

But we encounter first of all the fact that the two longitude values are presented in terms of the same symbols of the distances of the points. It may be that one of these solutions gives an impossible value of the sine. For several reasons the following seems to us the correct explanation.

The only law we have imposed on these distance symbols, so far, is that they must be only such distances as apply to points on the loci selected. Hence each of the points obtained in the solution will require its own set of the three distances.

Suppose the set of distances, determined by one of these points, and select that locus of the third set, which will pass through that point. That determines the time-difference of this locus, and so identifies the locus required. Using this equation with the equation of either of the intersecting loci, must give as one solution the point, by means of which the third equation was selected. But the second point of intersection involves distances, which correspond to the time-difference of this third locus. Hence, if it passes through one of the two intersections, it must also pass through the other.

From the manner, in which our loci were plotted, there should be a number of such double triplets of intersection. After two sets of loci have been drawn, and after all their points of intersection are clearly marked, it would not be difficult to name the third locus, which must pass through any pair of such intersections. But the only feasible proceeding is to draw the third set of loci. They will mark out the intersections. Our third sets—all of them—were drawn in just that way. They were plotted in, without any reference to existing intersections. All the charts show numbers of pairs of close triplets. Towards the limits of the charts the "triangle of error", to be expected, becomes rather evident, but, all in all, these triple intersections approve the consistency of the work to a very satisfactory extent, at least compared to the accuracy we expected.

But we meet with another trouble on the chart, when two loci run close together for long distances, intersect time and again, no third locus follows their lead, and our second degree equation, leaves room for only two intersections. Our second degree equation shows only that the uncontrollable distances determine the number of intersections of the two loci. That the intersections must come in pairs is due to the ovoid shape of our loci. Two regular ovals can intersect in four points. It may be that the second degree equation also indicates that one of these expected pairs of intersection is in abeyance in the case of our loci. This is no demonstration, but a conclusion, suggested, and seemingly borne out by a study of the position, size and form of our loci. The intersections of rambling loci are not of this regularly expected kind.

As a matter of fact two loci, each of a different set, often run long distances, in quite close proximity to each other. Taking any two close parts of such loci it will be readily seen that one is distinctly further from its base than the other, that one, therefore, is subject to a variety of kinking, which the other meets with somewhere else. Hence it seems quite necessary that they kink into each other here and there. The uniqueness of our solution of the second degree equation is then only apparent, and the source of the discrepancy is to be found in those varying distances, which cannot be eliminated from these equations. But if we find one such intersection, then there must be another. They must come in pairs. The dependence of the equation of the third locus on the two intersecting ones demands also that the same previous locus of the third set pass through both these new intersections. If all available loci had been drawn on our charts, all intersections would have been triple ones. Of course, a proceeding like the one just presented is hardly mathematical. It is partly based on unmanageable equations, partly on inspection of diagrams. If anything should come of our work, then a more rigid investigation may be worth while. Meanwhile this may serve as a temporary attempt at explanation. But, whatever value these surmises may have or not have, it is demonstrably certain that if two of our loci intersect at all, then they intersect in one or more pairs of points, and through all such intersections the same locus of the third set passes.

10. PROCESS OF LOCATING AN EPICENTER.

The first proceeding we suggest is based on the fact specified in the concluding sentence of the preceding section. We rely on the arrival times of the P tremors, to locate an earthquake.* If those times are not consistent, then a location of an epicenter by means of them is impossible. The principle, on which we tried to laud the consistency of our chart, serves also to test the consistency of these arrival times. Only in their case the demonstration is easy and peremptory.

As stated, the cones, with which our mathematical study begins, can be used to produce equations of our loci of the general form

$$Auv+Bu+Cv+D=0$$

Using the three cones pairwise gives three of these equations. We could do so little with them before, because they had so many irremovable variables. Now, when the three chart stations report the P tremors of an earthquake, these variables are ipso facto fixed. It happens thus. (To be definite, we must keep to the epicentral "point".) The epicenter is definitely somewhere. Therefore it is at a very definite distance from each of the three stations, and hence the transfer times to the three stations are very strictly determined. The actual distances do not appear on the face of the returns of the P arrival times. But the P arrival times indicate the locus of each set, on which the epicenter is to be sought. These three loci intersect mutually in two points at least, and these two points are determined by the simultaneous solution of the three equations, of the above form —or they appear as actual intersections on our chart, or as interpolated locations. Now suppose that two of the stations report the arrival time correctly, but the third is distinctly late. Such a time record or report would mean an epicenter at a distance greater than the true one. This would promptly introduce arbitrary changes in the constants C and D of two of the three equations—and the chances are slim that the three equations will then be simultaneously satisfied. In the case of our chart, the effect will be that the epicenter is referred to two wrong loci, each further away from the station with the false report, whilst the two stations with the correct report, keep the epicenter on the locus where it belongs. The three loci so assigned will not show pairs of triple interesctions.

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*The arrival times of P tremors are taken from the Shide Bulletins. See Note 4.

The same principle can be used with the same or even a better effect, if the epicenter is to be located by means of the S—P from three stations. The S—P is the actual distance from the station, which presents it, to the epicenter it should refer to. These actual distances enter into the coefficients C and D of the equations. If they are entered, and the three equations solved, the triangle of error will show an inadmissible magnitude, if one or other of the S—P values is greatly in error.

Theoretically this imports that the consistency of the (S—P)s, reported by any three stations whatever, can be tested by means of a single third order determinant placed equal to 0. In practice, the coefficients may deter one from a trial. Solved in this manner, and supposing correct distances, only one set of coordinates results.

Supposing the arrival times known correctly, the process of locating an epicenter on our chart, is merely one of tracing lines in that labyrinth. The differences of the arrival times will specify one locus of each set. One of the time-differences, it is hoped, is somewhere near the designation of a locus on the chart. If a locus with small time-difference, its frayed ends will be found somewhere on the outer limits of the chart. Find both its ends, and place a marker on them. Then find the next easiest locus to follow. Follow up both, until points of intersection are reached. Mark all such points of intersection.

As a rule, none of the time-differences obtained will refer to a locus, actually on the chart. In that case, the two loci, nearest to the epicenter are followed, until a rough interpolation shows that the neighborhood of the point sought is reached. Mark the neighborhood. The third locus, tracked into the same vicinity may then settle the matter, as we shall show in a few examples in the next section.

Again, one of only two sets of triple intersections may be off the chart, or so very far away as not to come into consideration. Then the near epicenter of a pair is probably the one sought.

If all intersections are near the stations, then anyone of them may be the point sought.

In that case a second chart, covering the same region, but having at least one of its three stations different from the set employed in the first chart will determine which is the point sought.

Should that third chart not be in existence, then one of the three chart stations at least, should be able to produce an S—P of some value. Even a roughly accurate value of that datum should enable one to pick out which of such points should be called the epicenter. The idea of earthquake regions may also be invoked, though what certainty can be claimed for that proceeding we are unable to specify.

In the succeeding section we shall try to apply these principles to some earthquakes, for which we have arrival times available. Should the process commend itself as in any way helpful or useful, we shall consider our labor as amply rewarded.

11. LOCATION OF SOME EPICENTERS.

Locations are given in just the order, in which we made them.

1. March 24, 1913.

Reported at Hamburg	10h 42.4m	Hence	P—V=0.1 minute
at Vienna	10h 41.3m		H—P=1.0 "
at Pulkowa	10h 41.4m		H—V=1.1 "

Ends of H—P=1, found in Longs. 120 and 160; of V—P=0, in Longs. 255 and 80.

These two loci do not intersect. They run close to each other for quite a distance. Near Long. 40, Lat. 45. P—V=0.1 minute, is on the V side of the bisector, hence still further away from H—P=1. Our times are given only to the nearest tenth of a minute. Hence .4m may be anything from 21 to 27 seconds, .3m, anything from 15 to 21 seconds. If the precise times were available, the loci they would indicate would intersect. However, place a marker in that parallel region, and find third locus. Small oval, H—V=1 pushes one little corner accross the PV bisector in just the parallel region marked. The third locus, H—V=1.1 is inside the oval, but near the line on the chart.

The location of epicenter, suggested by the three loci is very evidently the immediate neighborhood of Long. 39°, Lat. 44°.

The three loci diverge rapidly from that region, hence epicenter must be just there. The region is near the western end of the Caucasus Mts.

2. March 3, 1913.

Reported	at Hamburg	20h 14.3m	Hence	V—H=1.0 minute
	at Vienna	20h 15.3m		V—P=2.2 "
	at Pulkowa	20h 13.1m		H—P=1.2 "

Ends of H—P=1 in Longs. 120 and 160; of V—H=1; small oval, between Longs. 315 and 20, and between Lats. 50 and 75. H—P=1.2 is inside H—P=1. Hence it would intersect H—P=1 not far from extreme kink in Long. 18°, Lat. 68°.

V—P=2 forms triple intersections with V—H=1. V—P=2.2 is inside V—P=2. Hence indicates same as other two loci. Epicenter is near Long. 18°, Lat. 68°.

Rapid divergence of three loci permits no other location. Large time differences, for the stations in question indicate nearby epicenter. The reverse of this last statement does not hold. Region, Scandinavian Mts. near n. w. corner of Sweden.

3. March 27, 1913.

Hamburg reports	3h 21m	Hence	H—V=0.7m.
Vienna	3h 20.3m		P—H=0.2m.
Pulkowa	3h 21.2m		P—V=0.9m.

Ends of P—V=1 in Longs. 305 and 30; of P—H=0 in Longs. 230 and 60.

H—V= .7 = 42 seconds. Our locus H—V=40 seconds satisfies this requirement about as well as our time data permit. This locus is named in Long. 20°, Lat. 10°, is a closed locus, and is easy to follow.

P—H=.2m = 12 seconds is midway between H—P=0 and P—H= 20 seconds.

This locus would intersect P—V=40 seconds in about Long. 39° and Lat. —8°.

P-V=.9m=54 seconds is about trisector nearest P—V=1 minute of area between P—V=1m and P—V=40 seconds. Intersects H—V=40 seconds in about same point as above.

Hence one triple intersection is in Long. 39°, Lat. —8°.

Region, near e. coast Africa, south of Monfia Is.

Same three loci have common intersection in about Long. 23°, Lat. 51°.

Region, near n. e. corner Hungary.

No other intersections of these loci possible. A second chart would easily decide which of these two points is the epicenter. Even one S—P, at all reliable, would also decide the matter.

Service of third locus is shown well in case of southern point. H—V=40 seconds is cut almost normally by other two loci, and the latter run parallel courses through region. More loci in southern region would render location easy and certain.

4. March 31, 1913.

Hamburg reports	3h 52.8m	Hence V—H = .5m
Vienna	3h 53.3m	H—P = .9m
Pulkowa	3h 51.9m	V—P = 1.4m

One triple intersection can be made out with comparative ease in about Long. 24° and Lat. 57°. Region, well within station triangle.

The other intersection is difficult to locate. Somehow our "exercises"came to us in "graded" order, without any attempt on our part to make them so.

V—H=20 seconds ends in Longs. 180 and 290.

V—H=40 seconds, is closed, named in Long. 215, Lat. 65.

V—H=.5m = 30 seconds is midway between the two loci just named.

H—P=.9m = 54 seconds is trisector, nearest H—P=1m of area between H—P=1m and H—P= 40 seconds.

This locus would seem to intersect V—H=30 seconds in about Long. 180° and between Latitudes 47° and 57°.

V—P=1.4m = 1m 24 seconds. If our locus V—P=1m 20 seconds had been drawn, it would determine the intersection quite definitely. It certainly passes through the region specified above. If we accept the location named: Long. 180° Lat. between 47° and 57°, we would include the region named rather indefinitely by several locators as "Aleutian Isds."

These attempts at location seem to indicate the following

RULE, for loci to be drawn on chart.

1. All whole minute difference loci should be drawn entire.

2. The 20 and 40 seconds difference loci should begin near the station triangle, and should be continued thence to the limits of the chart.

3. The intermediate, 10 seconds difference loci should begin further out from the station triangle than the loci mentioned in 2.

4. 5 seconds difference loci would be very convenient near the limits of the chart.

5. Loci referring to smaller time-differences would be useless, so long as the ±1 seconds error of the arrival times must be reckoned with.

6. The loci, specified in 4 certainly, and probably those specified

in 3 could be interpolated by the method suggested at the conclusion of our second paper.

There are two more things we wish to illustrate. We did not select the order, in which the earthquakes, located above, were studied. We did reject, though, several, whose time returns were impossible, on the face of the reports. For instance:

5. March 18, 1913.

Hamburg reports 1h 54m.
Vienna 1h 31.4m H—P=15m
Pulkowa 1h 29m H—V=12m and more, quite impossible.

Same trouble, only less pronounced on March 23, 1913.

6. Sept. 17, 1911.

Berkeley reports 3h 35m 21s Hence S—B=5m.
St. Louis 3h 40m 23s S—O=3m.
Ottawa 3h 37m 23s O—B=2m.

All these loci are possible.

S—B=5m, small oval about B. Not on chart.

S—O=3m, small oval about O. Not on chart.

O—B=2m, almost bisects line Berkeley Ottawa.

From the data, as given in 5 and 6, it is impossible to decide which station made the return to which the trouble is due. A second chart, or rather, a set of second charts, would decide that matter.

7. One example of the use of a second chart.

Oct. 6, 1911.

Berkeley reports 10h 24m 55s Hence B—S=3m 2s
St. Louis 10h 21m 53s B—O=3m 4s
Ottawa 10h 21m 51s S—O=0m 2s

We can afford to neglect the odd seconds.

The three loci determined on our chart, by such omission, form two "triangles of error", one with its center in about Long. 290, Lat. 18; the other in about Long. 270, Lat. 48.

For the same earthquake, New Orleans reports 10h 20m.

O—N=1m 51s, is midway between O—N=2m and O—N=1m40s, both on the St. Louis-New Orleans-Ottawa chart. Both the loci mentioned are close together in the immediate neighborhood of the southern of the two points, located on the other American chart, whilst the same loci are nowhere near the northern point. This decides the case in favor of the southern point.

Location Haiti.

SECOND PAPER.

12. THE FORMULAE AND DEFINITIONS OF THEIR SYMBOLS.

Assume a spherical earth (Fig. 2). Through center O pass three axes: ON, passing through north pole of earth, OB, through intersection of Greenwich meridian with equator, and OQ cutting equator 90° east of B. Number longitudes from Greenwich eastward to 360°.

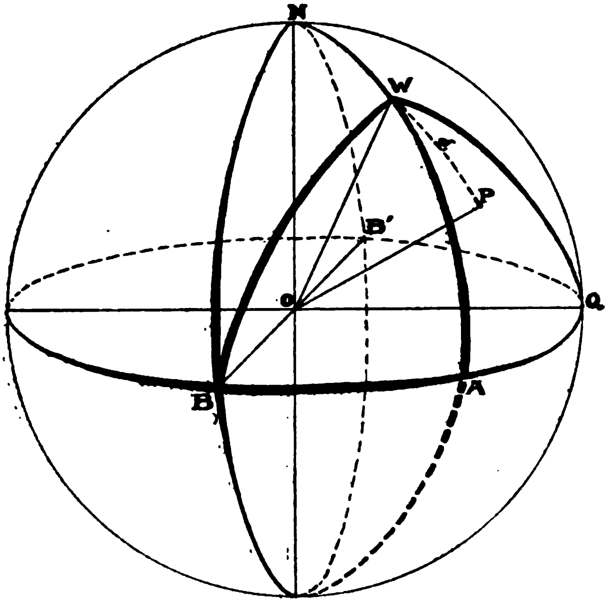

FIG. 2

A point, W, fixed in ϕ_1, λ_1, (AW, BA), is fixed with reference to the axes by the three position angles: α_1=WOQ, β_1=WOB and γ_1=WON.

From right triangles WAQ, and WAB, we get, by "Napier's Rules":

For W, fixed in ϕ_1, λ_1, and for E, fixed in ϕ_2, λ_2,

$$\begin{array}{lll} & \cos\alpha_1 = \cos\phi_1 \sin\lambda_1 = l_1 & \cos\alpha_2 = \cos\phi_2 \sin\lambda_2 = l_2 \\ & \cos\beta_1 = \cos\phi_1 \cos\lambda_1 = m_1 & \cos\beta_2 = \cos\phi_2 \cos\lambda_2 = m_2 \\ \text{also} & \cos\gamma_1 = \sin\phi_1 = n_1 \quad \text{and} & \cos\gamma_2 = \sin\phi_2 = n_2 \end{array} \qquad (1)$$

The point E is not shown in the figure. The relations for E follow from those for W, since the latter hold for any point on the globe.

Hence also for a point, P, in ϕ, λ, and with position angles α, β, γ,

$$\begin{aligned} \cos\alpha &= \cos\phi\ \sin\lambda = x \\ \cos\beta &= \cos\phi\ \cos\lambda = y \qquad (2) \\ \text{and } \cos\gamma &= \sin\phi. \end{aligned}$$

Radii WO and PO form angle WOP$=\delta_1$. Let $\cos\delta_1 = z_1$ (3)

Then angle WOP is determined by the relation:

$$\cos\delta_1 = \cos\alpha\ \cos\alpha_1 + \cos\beta\ \cos\beta_1 + \cos\gamma\ \cos\gamma_1,$$

or, replacing these terms by their symbols from (1), (2) and (3)

$$z_1 = l_1 x + m_1 y + n_1 \sin\phi. \qquad (4)$$

If we impose on radius OP no condition except (3), then will (4) be the equation of a right circular cone, with vertex at O and axis OW. This conical surface will cut the spherical surface in a circle, whose pole is W.

With radius OE, of station E, a second radius OP, for whose position cosines we adopt the values and symbols of (2), makes the angle EOP$=\delta_2$. Let $\cos\delta_2 = z_2$. (5)

Then will this second OP describe about axis OE the right circular cone

$$z_2 = l_2 x + m_2 y + n_2 \sin\phi. \qquad (6)$$

Now impose on δ_1 and δ_2, or, what comes to the same thing, on the arcs WP and EP, respectively, the law of growth, detailed in Sect. 7, Third. The intersections of the two cones (4) and (6) will then trace on the spherical surface one of the Time-Difference loci, of the set WE. For the coincident elements of the intersecting conical surfaces, the x, y and ϕ of (4) and (6) will have identical values.

Regarding (4) and (6) as simultaneous equations, we readily get:

$$x = \frac{m_2 z_1 - m_1 z_2 - (m_2 n_1 - m_1 n_2)\sin\phi}{m_2 l_1 - m_1 l_2} = \frac{M - N\sin\phi}{L} \qquad (7)$$

$$y = \frac{l_2 z_1 - l_1 z_2 - (l_2 n_1 - l_1 n_2)\sin\phi}{l_2 m_1 - l_1 m_2} = \frac{M' - N'\sin\phi}{-L} \qquad (8)$$

Next we obtain from (2): $x^2 + y^2 = \cos^2\phi$ (9)

and $x/y = \tan\lambda$ (10)

Combining (7) and (8) by (9), gives a simple second degree equation, with $\sin\phi$ as the sole variable, and this gives a solution of the form:

$$\sin\phi = \frac{A \pm [L^2(D-B) - C^2]^{\frac{1}{2}}}{D} \qquad (11)$$

For every value of sin ϕ, so determined, (7) and (8) by (10) give

$$\tan \lambda = -\frac{M - N\sin \phi}{M' - N'\sin \phi} \qquad (12)$$

From (2), (3) and (5) and the note following (6), it will be clear that the ϕ and λ, obtained in (11) and (12) are the geographical coordinates of points on that time-difference locus of the set WE, whose time-difference is the difference of the times, proper to the two deltas selected.

13. LOCATING AN EPICENTER BY MEANS OF A TIME-DIFFERENCE CHART AND THE S-P OF TWO STATIONS.

From (11) it is evident that A/D is the mean of the latitude sines of two points, each of which is at the distance δ_1 from W and δ_2 from E. Both the points are situated on the W side or on the E side of the great circle W—E=0, according as $\delta_2 - \delta_1$ is greater or less than 0. If we represent the radical by R, then will (A+R)/D be the latitude sine of the point on the north pole side of the great circle through W and E, and (A—R)/D will be the latitude sine of the point on the other side of the same great circle. This azimuth requirement can evidently be obtained from even a very rough Time-Difference Chart.

If the stations, from which the S-P values are obtained are both chart stations, there is no further difficulty. Otherwise a chart can be readily improvised for them, by roughly locating on a terrestrial globe the great circle through the stations, and the great circle bisecting the arc connecting the two stations. The former great circle will then decide, which sign of the radical is to be employed. This determined, the S-P of the two stations will be the two deltas of (3) and (5) respectively, and by means of them and the constants of the two stations, the terms of (11) and (12) can be produced readily.

The first paragraph of this section secures a single-valued sine of the latitude, and hence the latitude is determined unequivocally.

In case a series of points is determined, say with a view to constructing one of the loci of a Time-Difference Chart, the sequence of the longitudes would decide the matter of quadrants. When a single point is to be located, the longitude may be doubtful, so long as the matter is dealt with in this very general way. A few working directions will simplify the work considerably, and remove this difficulty as well.

14. SIMPLIFICATIONS FOR THE PURPOSE OF WORK.

The zero of longitudes is arbitrary, and for the purposes of this computation may be assumed anywhere.

Hence, proceed as follows:

Make no change whatever in the definitions and formulæ of section 12.

For W take the Western of the two stations, and for E take the Eastern station. These two letters were selected for that particular purpose. All the symbols with subscript 1 belong to the W camp, those with subscript 2 belong to the E camp.

Make the meridan of W the zero meridian, for the purpose of this work only.

This is done very simply by USING different values for λ_1 and λ_2. Namely, instead of λ_1, USE $\lambda'_1=0$, and instead of λ_2 USE $\lambda'_2=\lambda_2-\lambda_1$ When the work is done according to the formulæ, add to the longitude obtained the longitude of W, or if that should give a sum with a negative sign, add 360° more.

The longitude so obtained will be unambiguous, as a rule. Only, if the epicenter is in a very high latitude, it might be doubtful, whether a positive tangent longitude indicates the first or third quadrant, or whether a negative tangent indicates the second or fourth quadrant. A Time-Difference Chart may then decide the matter.

A brief outline of the numerical work may tempt some kindly disposed critic to give the formulæ an actual trial. The symbols of (1) are constants for their respective stations. Hence L, N and N′ of (7), (8), (11) and (12), and therefore D $(=L^2+N^2+N'^2)$ of (11) are constants for any pair of stations. Hence, for any pair of stations prepare logs of m_2, m_1, l_2, N, N′ and L^2, also D and its colog. Dispose these eight constants (computer fashion) about the edges of a card. M and M′ are determined by means of the first three of these constants and the cosines of the two deltas. Then $A=MN+M'N'$; $B=M^2+M'^2$ and $C=MN'-M'N$. The rest of the work is marked out unmistakably in (11) and (12).

Formula (11) indicates just how far the results are reliable. If the nth place in the value of D is certain, and if that value contains q significant figures, then the qth place of the sine latitude obtained is fairly certain, provided the nth place in A+R is certain. But to secure certainty about the nth place of A+R, several more places under the radical must be made certain. From the character of the operations required it is evident that if the work is based on an m-place table of sine functions (natural), then the mth place of the first derived result may be in error by ±1, or nearly that. Any figures beyond the mth place are not even ornamental, they are simply deceptive.

This very clear cut program is very satisfactory if known accuracy is the sole result aimed at. Any degree of precision may be secured by employing tables of the requisite amplitude. The usefulness of the formulæ ceases just where the precision aimed at ceases to warrant the extent of the work required.

The critical item is the value of D. It is always greater than zero, but its possible maximum does not seem to exceed .5 by much In general D increases as the latitudes decrease, though this rule seems to reverse near the equator. Again, D increases as the longitude difference of the two stations approaches 45°. For the short Hamburg-Vienna base, in a rather high latitude besides, D is not much greater than .01; for the St. Louis-Ottawa base it is more than .04; for the splendid Berkeley-Ottawa base it is more than .33. For two stations on the equator, and 45° apart $D=.5$ exactly.

The purpose of this last section is to simplify the work demanded by our formulæ. If the work is undertaken for the purpose considered in the preceding section, no more can be added now. If the work should be undertaken for the sake of computing a Chart, a further simplification suggests itself, which would supply besides a stringent test of the accuracy of the work, and also supply means for interpolating loci among those calculated.

This proposed simplification contemplates the computation, in one operation, of all the points at the same distance from the W station (instead of all the points on the same locus.) Here a number of other terms would become constant for just that operation, namely: m_2z_1, l_2z_1, and therefore M', $M'N'$, M'^2, $M'N$, would all be constant for any single operation. All these could be computed together as a preliminary to the work for the set, and then, for any operation, the pertinent constants could be "carded". This would shorten the columns very decidedly, in the first place. Then, plotting the points, derived from any single operation on a globe, should dispose them all on a circle, with W as pole. On the chart, therefore, they should lie on some sort of a battered ellipse, which would, however, be sufficiently regular to indicate instantly any delinquent calculation. No amount of "kinking" could interfere with such a reminiscence of an ellipse.

Suppose the calculated points measure up to the proper ellipse. Then, the latitudes, first, and the longitudes next, will be disposed in a sequence of numbers, which should show sufficient serial regularity to admit of a definitely determined interpolation. And herewith we must leave our work to its own devices.

Seismology and the Seismograph.[*]

Seismology, as we know it today, is the Benjamin of the Sciences. It has grown up within our memory. Fifty years ago it was believed that earthquakes were caused by explosions within a cavity in the earth's crust called the focus or centrum, and that the energy of these explosions travelled outward in straight lines as earthquake shocks which were soon dissipated.

In accordance with this theory Robert Mallet was commissioned by the Royal Society of Great Britain to determine the position and depth of the supposed cavity in the case of the great Italian earthquake of 1857. This he tried to do by establishing the normals to the fissure planes in the walls of damaged buildings and noting the directions in which debris had been thrown. These lines, he argued, should give the direction of propagation of the shock and should all intersect at the centrum.

Mallet's exhaustive report[†] was more than satisfactory to his own contemporaries, though it actually contains enough material to refute the centrum theory completely. Mallet did another great service to science. He introduced a number of needed terms which are still in use. The point on the earth's surface immediately above the focal cavity or centrum he called epicenter or epicentrum. The region about this point within which the shocks were most violent and destructive he called the meizoseismal area. About the epicenter he drew a system of closed curves; each curve passing through all places which suffered shocks of a given intensity. These lines of equal intensity, he called isoseisms or isoseismal lines after the manner of isotherms and isobars on the weather map.

The centrum or semi-volcanic theory of earthquakes accepted in Mallet's time was substantially that advanced by Artistotle 2000 years before, and it was given a new lease of life in 1872 by Prof. von Seebach[‡] in his studies on the Central German Earthquake of that year. But in the same year the first bomb was thrown into the centrum camp. In his work on the Calabrian and Austrian series of earthquakes, the great Viennese geologist Prof. Suess[§] showed conclusively that the epicenters of all the destructive earthquakes of both regions were ranged upon straight lines which marked the position of geological fault planes in the crust. Hence he divided earthquakes into two classes, tectonic quakes due to the slipping of vast masses or blocks of the earth's crust upon one another, and volcanic quakes or the minor, local shocks which accompany volcanic eruptions. The more earthquakes were studied the more evident did it become that Prof. Suess' classification was correct.

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[*] A lecture delivered before the Academy of Science, of St. Louis, Mo., by Prof. J. B. Macelwane, S. J., Professor of Physics in the St. Louis University.

[†] Robert Mallet, *The Neapolitan Earthquake of* 1857. 2 vols., London 1862.

[‡] K. von Seebach, *Das mitteldeutsche Erdbeben von 6 Marz* 1872. Leipsic, 1873.

[§] Edward Suess, Die Erdbeben des suedlichen Italien. *Denkschr. d. K-k. Akad. d. Wissensch. z. Wien; Math.-nathurw. Kl.*, vol. xxxiv, 1872, pp. 1-32, 3 pls. Die Erbeben Niederosterreichs, *ibid.*, vol. xxxiii, 1873, pp. 1-38, maps.

To illustrate the manner in which this readjustment of the earth's crust along fault planes takes place, Prof. Hobbs[*] has devised an experiment with blocks, to represent the blocks into which the earth's crust is divided.

A long rectangular tank or trough has one side of heavy plate glass which permits us to see what takes place within the tank. Across the trough near one end is a loosely fitting false end which is hinged to the bottom of the tank. An iron rod is so fitted through the false end and the opposite fixed end that objects fitting loosely between the two may be compressed as in a vise by tightening the bur on the rod. The tank is partly filled with water and a set of wooden blocks of varying lengths are floated loosely between. If the blocks are pushed down with a board until their tops are even and the bur is then tightened, they will be held in position by lateral pressure. This position is supposed to represent the unstable condition of the blocks of the earth's crust before an earthquake. There is a tension at many of the planes between the blocks and it is only the lateral pressure which prevents slipping. If this lateral pressure is slowly relieved by unscrewing the nut which holds the hinged end, there will come a time when readjustment will take place. The deeper blocks will slide upward and the shallower blocks will slide downward. This readjustment is what is conceived to take place in an earthquake. The illustration is, however, incomplete. Such blocks are far more rigid under the small stresses to which they are subjected than the earth blocks could possibly be under their stresses. A state of elastic strain is set up along the fault plane which causes a corresponding rebound when the rock gives way. This is aptly illustrated by an experiment of Prof. Reid.[†]

A sheet of gelatine three inches long, two inches wide and one-half inch thick was set between two small blocks of wood. A straight line, AC was drawn in ink on the jelly. The jelly was cut along the line tt′ and pressed together while the block on the left was shifted upward one-half inch. This sheared the jelly and the line AC took up the slanting position seen dotted in Fig. 4 On relieving the side pressure so that the friction could no longer keep the jelly in its strained position, the two sides slipped along the plane tt′ and the line AC broke into the two lines AB and DC. The distance between D and B being the distance the left block was originally shifted. A second experiment consisted in drawing a straight line A′C′ while the jelly was under strain. When the slip took place the line separated into the two parts A′B′ and D′C′, the distance D′B′ being the original displacement of the left side block. A third experiment was this: The left block was shifted one-half inch, thus straining the jelly. Then the straight line A′C′ was drawn upon it as before and the block shifted a quarter inch further, thus causing the line to take the position A″C′. When the slip took place along the line tt′ the line separated into the parts A″B″ and D″C′. In this last experiment notice that the total slip at the fracture was the sum of the two displacements of the left block; that the movement gradually decreases to zero at C′ on the right side of the fracture, while on the left it never becomes less than A′A″ the motion of the left block after A′C′ was drawn.

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[*] William H. Hobbs, *Earthquakes*, New York, 1907.

[†] Harry Fielding Reid, The Elastic-Rebound Theory. *Univ. of Cal. Publ., Bull. of the Dept. of Geol.*, vol. 6, No. 19, pp. 413-444' Berkeley, 1911.

This experiment illustrates very well what took place in the California earthquake. This region has been surveyed three times by the U. S. Coast and Geodetic Survey; once between 1851 and 1866, again between 1874 and 1892, and a third time after the last earthquake in 1906-7. In 1868, between the first and second surveys, a severe earthquake is known to have occurred in this region. Now the report of the U. S. Coast and Geodetic Survey for 1907 furnished us with the following facts: During the quake of 1868, or about that time, over 1000 sq. mi. of the earth's crust between Mt. Tamalpais, Farallon Light House, Ross Mt. and probably Sonoma Mt. moved northward as a block, a distance of about five feet. Mt. Diablo was not on this block and did not move. After this displacement, let us imagine a straight line drawn on the earth from Mt. Diablo to Farallon Light House, for the position of this line was actually determined by triangulation with a line from Mt. Tamalpais to Sierra Morena as a base. The survey of 1906-7 shows a further displacement of the Farallon Light House, after our imaginary Mt. Diablo-Farallon line was drawn, of about six feet to the northwest. Now what took place during the earthquake of 1906? Every road, every fence or row of trees that cross the fault shows a relative displacement parallel to the fault of from 7 to 21 ft., or about ten feet on the average for a distance of 185 miles. Regarding the absolute motion at any distance from the fault, the U. S. Survey officials, Hayford and Baldwin*, have deduced the following four characteristics or

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John F. Hayford and A. L. Baldwin, The Earth Movements in the California Earthquake of 1906,** ***Rep. of the Supt. of the U. S. Coast and Good Surv.**, Append. 8, pp. 69-104. Washington, 1907.**

laws (pages 81, 82). "First: Points on opposite sides of the fault moved in opposite directions, those to the eastward of the fault in a southerly direction, and those to the westward in a northerly direction. Secondly: The displacements of all points were approximately parallel to the fault. Thirdly: The displacements on each side of the fault were less the greater the distance of the displaced points from the fault. Fourthly: For points on opposite sides of the fault and at the same distance from it, those on the western side were displaced on an average about twice as much as those on the eastern side." Mt. Diablo, 33 miles east of the fault line, did not move. In fact no displacement could be detected with certainty at a distance greater than four miles east of the fault. Farallon Light House, 23 mi. west of the fault, moved about 6 ft. and the displacements of all points west of the fault apparently became equal to this amount at a distance of 6 to 10 mi. from the fault line. The total combined displacement of Farallon Light House for 1868 and 1906 was about 10 ft. The average relative displacement of points immediately adjoining the fault line on opposite sides was 10 ft. Thus far there is a perfect parallel between Prof. Reid's jelly experiment and the earthquake of 1906. But there is also a difference. The lines on the jelly after the slip were straight. The two parts of our imaginary Mt. Diablo-Farallon line were curved, the eastern portion being concave southward and the western portion concave northward. This is probably due, as Prof. Reid suggests, to the fact that the elastic forces are not applied at the outside edges, as in the case of the jelly, but are distributed throughout the entire strained portion of the crust.

The rapid tearing of a rift in the earth for a distance of over 200 mi. and a sudden slip of 7 to 20 feet would naturally cause a series of gigantic vibrations or waves in the solid earth. Such waves had often been seen, but it was thought that they were merely local phenomena associated with the meizoseimal area and never travelled to any distance. But a new era in the history of earthquake science was ushered in ,when in 1894, Prof. von Rebeur-Paschwitz noticed that his delicate pendulums were disturbed by earthquakes on the other side of the planet. This discovery marked the birth of the New Seismology. It was now possible, by suitably designed instruments, to observe earthquakes occurring anywhere on the globe. It is true that instruments had been used before, in regions of frequent earthquakes, to record the exact time at which a shock began. Such for instance, was the Chinese Seismoscope built by Chi-o-cho in the year 136 B. C. Inside a brass globe was suspended a pendulum. On the outside of the globe were eight dragons' heads, corresponding to the four cardinal points and four intermediate directions of the compass. In the throat of each was a ball which would be set in motion by any movement of the pendulum in that direction and would roll down and fall into the upturned, open mouth of a frog sitting below, thus indicating the direction of the shock. But such instruments were useless outside of the area affected by the shock and besides, told little of the nature of the motion. Prof. von Rebeur-Paschwitz' discovery, on the other hand, led immediately to the construction of the far more useful seismographs, which were to spread and increase in number until in 1912 there were 265 seismograph stations scattered over the globe.[*] Of the various countries Italy leads with 41 stations, the United States and the British Empire are next, each with 33 stations; then come Japan with 27, Germany with 25, Russia with 23 and Austria-Hungary with 18. The other 65 are scattered over 24 different countries.

The seismographs in use at these various stations may be divided into two general classes; the double horizontal and the single vertical pendulums. To the first class belong the von Rebeur-Ehlert, Milne, Omori, Mainka, and Galitzin types, and to the second the Vicentini, Agamennone, O'Leary and Wiechert types. The inverted types of the verticals such as the O'Leary and Wiechert, all depend on the action of springs, and are really intermediate between the horizontal and true vertical.

All of the horizontal pendulum seismographs require two separate instruments, one for each of the components, N-S and E-W. The object in using a horizontal pendulum instead of a vertical one is to lessen the effective component of gravity and thus to increase the period of vibration without unduly lengthening the pendulum itself. For if a horizontal pendulum with a period of 10 sec. were to be replaced by an ordinary vertical one with the same period, that vertical pendulum would have to be 81 ft. long. Still 10 seconds is not, by any means, a long period for a seismograph.

Seismographs in which the pendulum is vertical are either inverted or not. Examples of the latter class are the Agamennone and Vicentini. These seismographs are a compromise between length and period.

The O'Leary seismograph consists essentially of a heavy weight surmounting a long stem, supported in an upright position by a system of three steel wires attached firmly to a collar which surrounds the well in which the pendulum rests. The upright stands directly in the vertical and the restoring force which causes it to vibrate as a pendulum depends on the fact that the elastic stress in the wire increases faster than the effective component of gravity.

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[*] Siegmund Szirtes, Geographische Koordinaten der seismischen Stationen nebst Hilfstabellen. *G. Gerlands Beitr. z. Geophys.*, XI. Band, 2./4. Heft. Leipzig, 1912.

The Wiechert seismographs also contain an inverted pendulum. But the pendulum is not vertical. It is tilted just out of the vertical and is supported by delicate springs.

Now we come to the seismograph we have here in St. Louis. It was installed in a carefully insulated vault under the administration building of the St. Louis University, October 18, 1909. The instrument rests on a concrete pier 4x4x5.8 ft. walled off from the earth around it, leaving an air space of about two inches on all sides. Let me give you a more detailed description of the mechanism. Like other Wiechert seismographs it is an inverted pendulum tilted slightly out of the vertical. This pendulum consists of a heavy mass, weighing 80 kg. or 176 lbs. poised on a stiff rod about a yard long. The lower end of this rod terminates in a frictionless, universal joint formed by a Cardanic system of thin, flat springs. When the pier on which the instrument rests is set in motion by an earthquake, the cardanic hinge at the bottom and the entire frame of the machine move with the pier while the large mass at the top tends to remain at rest on account of its inertia. Archimedes said "Give me a place to stand and I will move the earth." Here we have a place to stand and watch the earth move around us, and if we want a record of this motion all we shall have to do is attach a pen to the stationary mass and it will make a trace on the moving frame.

But the pendulum will not remain upright in this unstable position without some means of support. It must be attached to the frame, yet so that it can remain stationary when the frame moves. This is ingeniously contrived by means of two thrust rods meeting at right angles in the center of percussion.

The instrument is so placed on the pier that the right thrust rod extends southward and the left one westward. Perpendicular to each thrust rod and in the same plane is a truss-like double lever. This lever is attached at its mid-point by means of a Cardanic hinge to an upward projection of the iron frame. This is the fulcrum of the lever. On either side are arms of equal length. One arm goes to the damping device, of which we shall have occasion to speak soon. The outer end of each thrust rod is fastened to this arm a short distance from the fulcrum. The arm on the other side leads to the mechanism which governs the motion of the pens.

By means of levelling screws in the base of the instrument, the pendulum with its large mass is tilted slightly toward the N-E. The force of gravity thus obtains an effective component and tends to make the pendulum fall over completely in that direction. The mass then pulls on the thrust rods and rotates the truss-like levers, pushing on their further ends. This push is transmitted through two little telescope rods which engage with the ends of their respective levers and with two other short levers which are pushed in the opposite direction by the torsion of two spiral springs on the axis of rotation of the pens. If either force is stronger than the other, it will rotate the pens and make a mark on the paper. If the effective component of the two forces due to gravity and the spring are equal the pendulum will be in equilibrium. Now if we take care that the effective component of the spring's force always increases and decreases faster than that of gravity, we shall always have a restoring force which will tend to bring the pendulum back to the position of equilibrium. But this same restoring force will keep the pendulum vibrating harmonically when once it is set in motion. This is a disturbing factor and will spoil our record of the relative motion between the earth and the stationary mass. For the mass will no longer be stationary when the earth moves. To obviate this difficulty as far as possible the damping cylinders are introduced. They consist of an air chamber inside which a piston is so suspended by little wire stays that it can move freely to and fro without touching the sides of the cylinder. But, in moving, this piston must overcome the resistance of the air. The air is sucked in behind the piston and driven out ahead of it through two holes whose size can be regulated. The resistance thus offered becomes greater, the faster the pendulum is moving. In this it differs from ordinary mechanical friction which must always be kept at a minimum. Mechanical friction curtails each stroke of the pen by a constant amount. The air damping does not. It makes each successive stroke of the pen on the paper bear a constant ratio to the preceding. This ratio is in our case 5:1, so that, if the pendulum be set in motion and cause the pen to mark one inch long the first time, the next mark will only be one-fifth of an inch long, the next one twenty-fifth, etc., and the pendulum will soon be practically at rest.

Such a contrivance becomes the more necessary the more closely the period of the earth waves approaches the natural period of the pendulum, which is in our case 7 seconds. I have here a wire with a loop which I place over my finger. Some distance down the wire I have attached a heavy ball of metal. My hand represents the earth. The loop represents the Cardanic hinge; the upper part of the wire is the pendulum, and the ball the heavy mass; while the long piece of wire extending below the ball represents the lever system and pens. If I move my hand back and forth very fast, the mass remains stationary and the pointer below indicates the motion, magnified, of course, in the ratio of the long wire to the short one. Now there is actually some length which we could give to a purely gravitational pendulum which would cause it to vibrate with the same period as our seismograph pendulum. That length would be about 40 feet. It would also be possible to attach a pointer to the pendulum which would be so long that it would magnify the motion of my hand to the same extent that the lever system of the seismograph magnifies the motion of the earth. The length of that pointer would be about three-fifths of a mile. Now suppose I move my hand more slowly. The pendulum mass no longer remains stationary and the motion of the pointer becomes exaggerated. The more closely I conform the motion of my hand to the natural period of vibration of the pendulum, the more violently does the pendulum swing. This is the phenomenon called resonance. From this demonstration I think you can see the necessity for damping, if we are to have a record of the earth's motion which is in any way faithful.

The demonstration also gives an idea how the true magnification changes with the period of the earth waves. If I move my hand very slowly the pendulum will follow my hand and there will be no relative motion recorded at all. The number of times the pointer is longer than the pendulum we call the indicator magnification or magnification for very rapid vibrations. Prof. Wiechert's chart will show the relation of the true magnification to the indicator magnification for various earth-wave periods and damping ratios.

We often wish to know the exact distance through which each particle in the earth under the seismograph has moved. But, as we have seen, the magnification for each wave may be different. Hence the calculation of the earth motion is a tedious process, but is very much shortened by the use of a logarithmic chart made by Dr. Geiger of Gœttingen, Germany, which gives us the earth-motion corresponding to one millimeter on the trace or seismogram for any particular wave.

Any of you who are interested in the physics of the Seismograph I would refer to the Bulletin of the St. Louis University for December, 1911, as time will not permit us to treat the matter further tonight. Standard works on the mathematics of the subject are Wiechert's *Theory of Automatic Seismographs* in German, and Reid's *Theory of Seismographs* in the second volume of the Report of the State Earthquake Investigation Commission on the California Earthquake of 1906.

Let us proceed now to the trace made by the Seismograph.

We take a sheet of paper about one yard long, bend it around, paste the two ends together, put it on rollers and rotate it over a long kerosene flame until it is covered with a fine film of soot. It is then placed on the recording cylinder of the seismograph and rotated uniformly by clockwork at the rate of one centimeter per minute, that is about two inches every five minutes. The fine aluminum recording pens rest lightly upon it. In fact the pressure is not greater than 1 milligram or .00004 of an ounce,

Suppose now that the waves from a distant earthquake strike the seismograph. The motion will be split up into two components, N-

and E-W, by the two thrust rods. Near the earthquake epicenter the waves will all be crowded together. But if the waves have come from a distance they will be separated out into definite groups. There are three distinct sets, the first preliminaries, second preliminaries and main waves. We have the same groups or phases in the record of the Persian earthquake of Jan. 23, 1909, made by the large Wiechert seismograph at his own station in Gœttingen and also in the seismogram of the Mexican earthquake of June 7, 1911, recorded at the St Louis University. Each of these sets of waves on the record corresponds to a particular kind of wave in the earth. The first preliminary waves are longitudinal waves of compression and rarefaction like sound waves. The second preliminaries are transverse waves of distortion like light waves. Both of these go through the interior of the earth. The main waves are complex surface waves like water waves which go around the outside of the earth. All three sets started out together but the longitudinal waves travel faster than the transverse waves, and these again faster than the surface waves. So the farther the earthquake station is from the epicenter, the greater distance there will be between their records on the seismograph. If we know the time it takes for each to travel a certain distance and hence the amount by which each falls behind the other for a given distance, we need only observe the number of minutes by which the second preliminaries have fallen behind the first and we have the distance of the earthquake. Tables are used for this purpose which are derived from the Weichert-Zoeppritz transmission curves. The ordinates or vertical lines to each curve represent the time in seconds required for that kind of waves to reach a station whose epicentral distance around the surface of the earth is represented by the abscissae, each large vertical space representing 500 seconds and each large horizontal space representing one megameter or about 621 miles. Curve No. 2 gives the transmission time for the first preliminaries. Curve No. 3 for the second preliminaries and Curve No. 5 for the surface or main waves.

Now it is not always possible to distinguish the phases with certainty, as in the record of an earthquake in Swan Island in the Caribbean Sea obtained at the University Jan. 1, 1910.

Even in the case of such records as the three we had before and also the one of the Mexican earthquake of Dec. 16, 1911, in which the phases are very clear and distinct, we have not yet *located* the earthquake by the mere fact that we have determined the distance. For this condition would hold equally well for all points on a circle with St. Louis as center and that distance as radius.

In certain exceptional cases, however, in which the earthquake record begins with a decided impulse, as in the one now on the screen, we may proceed in this way. The two sets of lines represent the two components into which the motion is broken up by the thrust rods. An impulse from the west will make a downward stroke on the upper line and one from the east an upward stroke. Also an impulse from the north will make a downward stroke on the lower line and one from the south an upward one. In this case we find an upward impulse on the upper line and a downward impulse on the lower. This means that the shock came from somewhere between north and east. This might have been produced either by a condensation from the northeast or a rarefaction from the southwest. The distance given by the interval between the first and second preliminaries was 2690 km, or about 1670 miles. Now we know by experience that we do not get earthquakes of this character from Labrador. This record bears a decided Mexican stamp. So we take our microscope, measure each impulse exactly, and calculate the corresponding earth motion. We find them to be .0005 inch W, and .001 inch S. approximately. Combining these two values in the parallelogram of forces and calculating the exact azimuth or direction, we can go to our map on which we have direction lines and distance circles plotted for St. Louis and put our fingers on the exact spot off the west coast of Mexico between Acapulco and Colima. This we telephoned to the newspapers within an hour after the record was removed from the machine. This method is known as that of Prince Galitzin. Other methods required data from at least three stations before they can be applied.

I would respectfully refer anyone who is interested in these methods to the Bulletin of St. Louis University for April, 1912, and also to the forthcoming April Bulletin.

Before leaving this subject, I wish to call your attention to the fact that if we had the Wiechert instrument for the vertical component when we were working out the data for that Mexican earthquake there would not have been any ambiguity, for the impulse would have been downward and earthquakes do not come from the sky.

Like all vertical seismographs, the Wiechert consists of a heavy mass, in this case 80 Kg. or 176 lbs., supported by springs and free to vibrate in a vertical plane.

People nowadays are always looking for results from Science. By this they usually mean applications of the knowledge gained to the problems of other fields of endeavor. Judged from this standpoint has seismology any results to offer? From a practical and economic point of veiw, the knowledge of the nature of seismic vibrations has been of material assistance to the building engineer and is leading to saner and safer construction, especially in those regions that are exposed to earthquakes. But it is to the geologist and geophysicist that seismology has been the greatest boon. Before the advent of seismology the interior of the earth was a sealed book. The depth which was reached by mines and borings can scarcely be called a scratch on the surface. According to various vague assumptions we were led now to a molten liquid earth surrounded by a thin crust, now to a gaseous interior. Seismology proves beyond doubt that the interior of the earth, whatever its condition, behaves as if it were a solid more than twice as rigid as steel. The earth seems to be made up of an outer mantle of rock in which the velocity of seismic waves rapidly increases down to a depth of 1200 km; a layer of metal, apparently nickel steel, in which the velocity increases very slowly, and an inner metallic core at a depth of 3000 km., which casts a seismic shadow on the other side of the globe and in which the velocity seems to be somewhat less, though it is very hard to study. Thus like the rays of light from the distant stars that bring us, through their spectra, some knowledge of the chemical constitution of the bodies from which they come, the seismic rays from the interior of our planet seem destined to open before our mental vision those dark and mysterious depths.

Record of Earthquake Station, St. Louis University for 1913.

ST. LOUIS, MO., U. S. A.

LATITUDE: 38° 38′ 17″ N.
LONGITUDE: 90° 13′ 58″.5 *or*
$6^{h}.\ 0^{m}.\ 55^{s}.9$ W. Gr.
ALTITUDE: 160.36m.
TIME: Mean Greenwich, midnight to midnight.

INSTRUMENT: Wiechert 80 kg., astatic, horizontal pendulum.
FOUNDATION: 12 ft. of tough clay over limestone of Mississippi System; thickness of latter about 300 ft.

NOMENCLATURE: International.

The symbols used in the following record are those of the *International* Nomenclature, which is identical with that given by us in the December Bulletin of the University (1911).

SYMBOLS.

CHARACTER OF THE EARTHQUAKE.

I = noticeable, II = striking, III = violent.

d = terrae motus domesticus) = local earthquake (felt at station).

v = (terrae motus vicinus) = nearby earthquake (less than 1000 km.).

r = (terrae motus remotus) = distant earthquake (1000-5000 km.).

u = (terrae motus ultimus) = very distant earthquake (more than 5000 km.).

PHASES:

P = (undae primae) = first preliminary tremors (longitudinal waves through the earth's interior.)

PRn = P waves reflected n times at the earth's surface.

S = (undae secundae) = second preliminary tremors (transverse waves through the earth's interior).

SRn = S waves reflected n times at the earth's surface.

PS = transformed waves, i. e., waves which, in their reflection at the earth's surface, have been changed from longitude to transverse, or vice versa.

L = (undae longae) = long or "Rayleigh" waves (first phase of main or principal portion—surface waves).

M = (undae maximae) = greatest motion in the main or principal portion (complicated surface waves).

C = (cauda) after-shocks or trailers.

F = (finis) = end of visible motion.

NATURE OF THE MOTION:

i = (impetus) = sudden impulse.

e = (emersio) = gradual development (beginning uncertain).

T = period =time of complete vibration to and fro.

A = amplitude of earth motion—reckoned from the line of rest and measured in microns, ($\mu = 1/1000$ mm).

E or N attached to a symbol refers it to the E-W or N-S component.

EARTHQUAKE RECORDS FOR 1913.

Date	Char.	Phase	Time	Period T	Amplitude		Remarks.
					.AE	.AN	
			h. m. s.	s.	mm	mm	
Jan. 11	I	$?P_E$	18: 39.				Contact clock
		$?P_N$	18: 39: 06				slightly inaccurate
		L_N	13: 54. 48				
		L_E	13: 54.				
		F_E	15: 37.				
Jan. 15	Ir	iP_N	18: 58: 3	3		.6	E-W very faint
		eP_E	18: 58: 4				Distance about 3000 km.
		PR_{1N}	18: 58: 8	4-6		1.	
		S_E	19: 02: 8				
		S_N	19: 02: 8	5		.5	
		L_E	19: 03: 8	6-9			
		F_E	19: 40.				
Feb. 18	I	$?e_N$	00: 47: 1				
		L_N	00: 52: 7	9			
		F	8: 15: 5				
Mar. 3	II	e	3: 12: (?)				Record very imperfect.
		$?S_E$					
		L_N	3: 18: 5	10-12			$T_E = 6.8$ sec.
		L_E	8: 19: 8	10-11			$T_N = 7.8$ sec.
		M_N	8: 20:	10		8	$\varepsilon_E = 5.1$
		F	3: 48: 5				$\varepsilon_N = 6.2$
Mar. 4	Iu	S_N	11: 29: 50				
		S_E	11: 30: 14				Distance = 4450 km.
		$?SR_E$	11: 32: 15				Periods and amplitudes
		L	11: 34:				exceedingly slight.
		F	11: 50:				
Mar. 8	IIr	$?P_N$	15: 57: 01				
		S	16: 02: 41	4-10			Distance = 3800 km.
		M_N	16: 02: 50	10			Beginning of Phases indistinct.

Date	Char.	Phase	Time	Period T	Amplitude		Remarks.
					AE	AN	
			h. m. s.	s.	mm	mm	
Mar. 8		eL	16: 06: 12				continued.
		L_N	16: 11: 36	10		.4	$T = 7$ sec.
		C_N	16: 12: 36	10			$\varepsilon_N = 6.2$
		F	16: 38: oa				$\varepsilon_E = 6.1$
Mar. 9		L	16: 30: 24				
Mar.14	IIu	P	9: 05: 58				
		S	9: 15: 59				
		?eL_N	9: 27: 55				
		?eL_E	9: 32: 01	12			
		L_E	9: 41: 07	40	.4		
		L_E	10: 04: 44	15	.5		
		F	11: 14: 00				
Mar.15	I	?e	22: 29.7				N-S disturbed by wind-quakes.
		eL_E	22: 33: 22	6			
		F_E	22: 52				
Mar.31	IIu	P	3: 51: 14				
		S_E	3: 59: 31				Distance = 6800 km.
		S_N	3: 59: 33				On N-S there are
		L	4: 022 12	33			seven distinct main
		M_{N1}	4: 15: 35	20		.7	shocks and three
		M_{E1}	4: 15: 59	19	4		after shocks.
		M_{N2}	4: 17: 37	18		.9	$T_E = 7$ sec.
		M_{E2}	4: 17: 45	14	.7		$T_N = 7.2$ sec.
		M_{N3}	4: 19: 48	14		1.	$\varepsilon_E = 5.8$
		M_{E3}	4: 19: 48	16	.8		$\varepsilon_N = 6.3$
		M_{E4}	4: 22: 49	11	.6		
		M_{N4}	4: 28: 21	18		.9	
		M_{N5}	4: 27: 58	12		.6	
		C_N	5: 03: 45	10		.4	
		C_{E1}	5: 03: 45	10	.2		

Date	Char.	Phase	Time	Period T	Amplitude AE	Amplitude AN	Remarks.
			h. m. s.	s.	mm	mm	
		C_{E2}	5: 09: 14	10	.2		
		F_N	5: 18: 30				
		F_E	5: 30: 00				
Apr.25	I'	?e	18: 23: 42				
		L_E	19: 00: 30				
		L_N	19: 02: 07	20			
		L_E	19: 11: 06	18			
		F	19: 59:				
Apr.26	Ir	P_E	12: 43: 49				No.L on E-W.
		P_N	12: 43: 51				
		S	12: 48: 50				Distance 3250 km.
		$?eL_N$	12: 51: 00				
		L_N	12: 54: 14	15			
		?F	13: 15:				
Apr.28		i_E	00: 34: 27				Local earthquakes felt along the St. Lawrence.
		i_N	00: 34: 35				
Apr.29		L_E	00: 05: 30	15			
		L_N	00: 07: 25	15			
		?F	00: 25				
Apr.30	Iu	?S	11: 52: 15				Distance 8000?km.
		L_N	12: 04: 58	17			
		L_E	12: 04: 59	14-16			
		F	13: 57.				
May 8		e_E	18: 51: 48				Record very slight. Masked by local microseisms.

Date	Char.	Phase	Time	Period T	Amplitude		Remarks.
					AE	AN	
			h. m. s.	s.	mm	mm	
May 16	I	$?eL_E$	12: 11: 15	10			
		$?eL_N$	12: 11: 17				
		F	12: 30: 00				
May 30	Iu	$?eP_N$	11: 54: 58				Distance = 18000? km.
		$?eP_E$	11: 58. 18				T = 7 sec.
		e_E	12: 02: 35				$\varepsilon_E = 4.5$
		e_N	12: 02. 42				$\varepsilon_N = 6.8$
		eL_N	12: 34: 20	54		.4	
		eL_E	12: 35. 30				
		L_E	12: 50: 32	20	.5		
		L_N	12: 53: 36	15		.6	
		F_E	14: 08: 30				
		F_N	14: 09: 55				
Jun. 22	Ir	eP	13: 59: 36				
		R_1P_N	14: 02: 12				Distance = 6500 km.
		eS	14: 07: 42				Quake reported from the
		$?R_1S_N$	14: 12				Aleutian Islands.
		$?eL_N$	14: 17. 24				
		$?eL_E$	14: 17. 48				
		M_E	14: 26	17	.5		
		M_N	14: 27. 30	16		.7	
		F	15: 12.				
Jun. 26	Ir	?eP	5: 11: 30				
		$?eS_N$	5: 18				Distance = 4900 km.
		R_1P_E	5: 18: 15				Microseisms on N-S
		eL_E	5: 28: 01				render determination
		$?eL_N$	5: 28: 50				of S impossible.
		M_E	5: 45: 18	26	.8		
		M_N	5: 48: 54	21		.7	
		F	7: 36.				

Date	Char.	Phase	Time	Period T	Amplitude		Remarks.
					AE	AN	
			h. m. s.	s.	mm	mm	
Jul. 8	Ir	eP_N	00: 17:				
		$?eP_E$	00: 17: 05				Distance = 1900 km.
		eS_N	00: 20: 16				
		eS_E	00: 20: 23				
		eL_E	00: 20: 59				
		eL_N	00: 21: 58				
		M_N	00: 23: 17	10		.7	
		M_E	00: 25: 39	8	.4		
		F_N	00: 40:				
		F_E	00: 42:				
Aug. 1	II	?e	17: 33: 02				
		?eL.	17: 52: 50				
		F	18: 30				
Aug. 6	II	$?eP_E$					
		e	21: 21: 15				Distance = 3600 km.
		$?eP_E$	21: 24: 06				Quake reported from
		P_N	21: 24: 22				Peru.
		$?S_N$	21: 29: 19				
		$?eS_E$	21: 29: 30				
		eL_E	21: 31: 58				
		L_N	21: 32: 12	12			
		M_E	21: 44: 55	30	.9		
		M_N	21: 48:	21		2.1	
		M_{E2}	21: 50: 01	20	1.2		
		F	22: 50				
Sep. 8	I	$?E_N$	21: 18: 46				Reported in Sicily.
		$eS_E?$	21: 18: 58				No decided M.
		eL_E	21: 47: 58				
		F	22: 27:				

Date Char.	Phase	Time	Period T	Amplitude		Remarks
				AE	AN	
		h. m. s.	s.	mm	mm	
Oct. 2 · IIr	eP_N	4: 29; 47				
	$?PR_{1N}$	4: 30: 41				Distance = 3100 km.
	eS_N	4: 34: 13				Panama
	$?S_E$	4: 35: 53				
	eL_N	4: 36: 17				
	$?eL_E$	4: 39: 04				
	M_{N1}	4: 41: 11	9		.5	
	M_E	4: 41: 15	8	.4		
	M_{N2}	4: 46: 09	11		.6	
	F_N	5: 08.				
	F_E	5: 18				
Oct. 4	e_N	22: 11: 39				Microseisms especially
	e_E	22: 11: 06				on E-N.
	F	22: 29.				
Oct. 11	$?eP_E$	2: 08: 16				
	$?eL_e$	2: 35:				
	eL_e	2: 43;				
	F	2: 57				
Oct. 11 IIr	eL_N	5: 05: 38				
	eL_E	5: 16: 42				
	F	5: 35				
Oct. 14 Ir	eP_E	8: 27: 38				
	R_2P_E	8: 33: 12;				
	R_3P_E	8: 34: 22				
	$?eS_E$	8: 38: 06				
	R_1S_E	8: 44: ?				
	F	8: 55;				

Date	Char.	Phase	Time	Period	Amplitude		Remarks.
				T	AE	AN	
			h. m. s.	s.	mm	mm	
Oct 23	Ir	?eP	15: 08: 26				
		eS	15: 13: 14				
		eL	15: 15: 25				
		M_E	15: 16: 19	9	.3		
		F	15: 44				
Nov 23		e_E	21: 34: 17				
Nov 26		$?i_N$	7: 01: 00				Microseisms prevail
		?φ	7: 04				
Dec 6		e_E	0: 26				
		e_E	0: 31: 12				
Dec 6		?e	11: 08: 35				
		$?i_E$	11; 14: 46				
		?e.	11: 19: 27				
Dec 15			23: 59				Microseisms continually before midnight
			24: 14: 06				
			24: 48: 02				
Dec 21		$?eL_E$	16: 42: 25				Microseisms
		eL_N	16: 43				
		M_N	16: 46: 12		.8		
		F	17: 00;				
Dec 28		?e	12: 08: 12				Microseisms prevail remarkably from Dec. 26th to Jan. 1st 1914
		$?_i$	12; 18: 49				

PART II.

METEOROLOGY

LOCATION OF METEOROLOGICAL OBSERVATORY.

Latitude: 38° 38′ 17″ north.

Longitude: 90° 13′ 58″.5 west.

Elevation: 578 ft. above sea level.

Wind Vane: 94 ft. above ground.

Anemometer: 96 ft. above ground.

Top of Rain Gauge: 80 ft. above ground.

Floor of Thermometer Shelter: 10 ft. above roof and 86 ft. above ground.

Explanation to Meteorological Summaries.

Atmospheric Pressure in inches reduced to mean sea level.

Mean Temperature: $\frac{\text{Maximum} + \text{Minimum.}}{2}$

Mean Vapor Pressure and Mean Relative Humidity: The mean of the two daily readings of the various thermometers reduced according to the method used by the U. S. Weather Bureau.

Equipment.

The present equipment of the observatory consists of the following instruments:

1.) Fortin Barometers.
2.) Barograph, Richard Bros. pattern.
3.) Thermograph, Richard Bros. pattern.
4.) Maximum and Minimum Thermometers.
5.) Whirling Psychrometer.
6.) Hygrograph.
7.) Thermograph.
8.) Tipping Bucket Rain Gauge.
9.) Snow Gauge.
10.) Electrical Sunshine Recorder.
11.) Jordan's Photographic Sunshine Recorder.
12.) Wind Vane.
13.) Anemometer (Robinson).
14.) Meteorograph (Quadruple Register).
15.) Ceraunograph (Lightning Recorder).
16.) Ceraunophone.
17.) Thermostatic and Temperature Alarm.
18.) Ground Thermometers.
19.) Several Standard Thermometers.
20.) Telethermoscope.
21.) A Complete Receiving and Transmitting Set for Wireless Telegraphy.

THE WEATHER OF 1913.

The year 1913 was remarkable in St. Louis and its vicinity for the prevailing high temperatures and unusually dry weather. The summer months of June, July and August were among the warmest and driest recorded during 76 years. Fifty-five of the 92 days showed a maximum temperature of 90 degrees or above, and on eight of these, the thermometer registered 100 degrees or above. Beginning with June 12 till September 13 the temperature never went below 60 degrees. The average maximum for the season was 91 degrees, and the average minimum 70 degrees.

The rainfall of the three months was distributed over only 17 days with a total of 9.42 in., which is two inches less than the usual amount, and the most of this fell during very short periods. June showed 13 consecutive days without rain; another dry period lasted from July 28th till August 12; the longest period of drought extended from August 22 to September 7th.

A comparison of ground temperatures for the winters of 1912 and 1913 is significant of the mildness of the latter season. The lowest ground temperature of 1913 was 49° as compared with 38° in 1912, the temperature being taken 5 ft. below the surface. The difference of 11 degrees in ground temperatures and the fact that the average of the present winter was 6 degrees above the normal illustrates the mildness of the season.

JANUARY.

The year opened with temperature reading above the normal; the mean for the first week being 32.5 and for the entire month of January 34°, four degrees above the normal for this month. The lowest temperature, 7°, occurred on the 12th, and the highest, 63°, was registered on the 19th. The precipitation, 4.89 in. was well above the normal of 2.27 in. The precipitation of snow, however, 1.1 in., was unusually slight, compared both with the normal and the amount, 19 in., for the corresponding period in 1912. Sleet occurred on four days; heavy fog on seven days, and an unseasonable thunderstorm on the 7th of the month. The average daily sunshine recorded was 37 per cent.

FEBRUARY.

February opened with a temperature of 4°, the lowest mark reached during the year, and for seven successive days the mercury remained below the freezing point. This cold wave was followed by moderate high temperature until the 18th, which recorded a daily range of 27°, the greatest of the month, and a maximum temperature of 68°, the highest for this day since 1836. The mean temperature of the month was 30.3°.

The precipitation for the month, including melted snow, totalled 1.40 in. less than half the normal; 7 inches of snow were registered as against 34 inches in February 1912.

Sleet occured on three days, dense fog on three days, and a thunderstorm on the 21st of the month. The average daily sunshine recorded was 50 per cent, with 12 clear, 12 cloudy and 4 partly cloudy days.

MARCH.

March opened with a cold wave reaching a minimum of 4° on the 2nd, the equal of the lowest temperature of the year already recorded on February 1st. This cold wave was of short duration and the mean temperature of the month shows 22 days above freezing point. The highest temperature, 75°, was recorded on the 30th. The mean temperature for the month, 42°, was two degrees below the normal.

The month was remarkable for the amount of recorded precipitation, 8.83 in. This not only exceeded the normal, 3.43, but surpassed by more than 3 in. the record of any month in the year. The total amount of unmelted snow 10.8 in. was in excess of that recorded for this month in 75 years, the previous high figure being 8.61 in. for 1865. On the 24th of the month 3.75 in. of rain fell within the space of 24 hours.

There were 5 thunderstorms, two hail storms and dense fog occurred on two days. The average daily sunshine was 50 per cent, with 12 clear, 13 cloudy and 6 partly cloudy days.

APRIL.

The month of April was mild and pleasant with no extreme temperatures, no killing frosts and no other remarkable phenomena. The mean temperature, 56° was exactly normal, and the precipitation 3.75 in. practically so. The lowest temperature was 38° and the highest 84°, the greatest daily range of 30° occurring on the 17th. The sunshine record of 64 per cent was remarkably high;—the number of clear, cloudy and partly cloudy days being 18, 10 and 2 respectively. A genuine "Spring Month."

MAY.

The mean temperature for this month was 67.3°; the lowest point 42° was recorded on the 10th, the highest 94° on the 30th and the greatest range of 30° on the 28th.

Indications of the drought, which was to make this year disastrous to the farming interest of the middle West, began to show themselves in May. The total precipitation of 1.42 in. fell far below 4.59 in., the normal for 75 years. The first 25 days showed a precipitation of but 0.75 in., the lowest recorded for this period during the present year.

The average daily sunshine was 66 per cent, with 16 clear and 9 partly cloudy days.

JUNE.

Unfavorable weather conditions continued during the present month, with temperature above and precipitation below the normal. On 16 days of the month the thermometer registered 90° or above, and on 10 of these days the mercury reached 95° or more. The maximum 99° was reached twice during the month, on the 18th and the 29th. The mean temperature of 78° was 3 degrees above the normal. For the last sixteen days of this period the average maximum temperature reading stood at 94.6°.

The total precipitation distributed over but 4 days amounted to 3.23 in. as against the normal for the month of 4.81 in.

The average daily sunshine was 75 per cent, with 19 clear, 4 cloudy and 7 partly cloudy days. A hail storm occurred on the 22nd.

JULY.

Assisted by prevailing North winds and consequent excessive rains, July opened with a decided fall from the prevailing high temperatures of the last week of June. But this welcome relief was of short duration. Fifteen days of the month reached 90° or above and 100° was reached on 3 days, the 17th, 18th, and 29th.

The excessive rainfall of July 1st, 2.78 in., of which almost 2 in. fell within 20 minutes, constituted over one-half the precipitation for the month. During the remaining days of July the precipitation was but 1.76 in.

The normal for the month during the past 77 years was 3.81 in.

The sunshine record showed 72 per cent, with 17 clear, 3 cloudy and 11 partly cloudy days.

11 thunderstorms and 1 hail storm were observed during this time.

AUGUST.

This month with an average daily maximum of 93.6° and a mean of 82.8° was the hottest August since 1900, and one of the warmest ever recorded in the vicinity of St. Louis. The highest mark of the month and of the year, 102° was reached on the 6th. On 23 days a maximum temperature of 90° or higher was recorded, and on 5 of these days 100° or more were registered.

The precipitation was 1.65 just one half of the normal for 76 years. This slight rainfall was distributed over but four days. The combination of slight precipitation and excessive temperature proved disastrous not only in the vicinity of St. Louis but throughout the entire Middle West. All late crops were destroyed, cattle perished and this entire section of the country was a blazing furnace without periods of even temporary relief.

The average daily sunshine was 73 per cent, with 18 clear, 3 cloudy and 10 partly cloudy days.

SEPTEMBER.

The crest of the intolerable hot wave was reached during the first four days of September which recorded an average maximum of 99.8°. During the succeeding week the heat wave gradually receded, and on the 12th of the month a maximum of 67° marked the termination of the intolerable temperature of the Summer of 1913. During the latter half of the month temperatures were well below the normal and the average for the 30 days was 70°. A minimum of 40° was recorded on the 22nd.

The high precipitation of 5.37 in. distributed over 13 days was for the most part too late to be of advantage to the farming interests of the section.

The average daily sunshine was 57 per cent, with 13 clear, 10 cloudy and 7 partly cloudy days.

OCTOBER.

October presents no unusual weather conditions beyond an excessive rainfall of 5.02 in. and a Killing Frost, the first of the season, on the 28th. The mean temperature of the month was 55° with a maximum of 82° on the 6th and minimum of 27° on the 29th.

The average daily sunshine was 53 per cent, with 12 clear, 13 cloudy and 6 partly cloudy days.

NOVEMBER.

The month of November was unusually warm, having a mean temperature of 52°, 9 degrees above the normal for 77 years. The maximum was reached on the 21st with a temperature of 76°; while the minimum of 26° was reached on the 11th.

The precipitation 3.23 in., distributed over 10 days, was somewhat in excess of the normal for the month of 2.95 in.

The average daily sunshine, 36 per cent, was unusually low, with 6 clear, 16 cloudy and 8 partly cloudy days.

DECEMBER.

The mean temperature for this month was 39.7° with a maximum of 60° on the 2nd and the 6th, and a minimum of 22° recorded on the 8th.

The precipitation, including melted snow, aggregated 2.29 in. slightly below the normal of 2.51 in.

The month was remarkable only for its excessive cloudiness, the sun was invisible for the last 10 consecutive days. The average daily sunshine was but 31 per cent, or 93 hours out of the possible 297. There were 7 clear, 3 partly cloudy and 21 cloudy days. Fog was recorded on four days.

JANUARY 1918

Date.	Pressure.		Temperature.				Moisture				Wind.				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7. A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum.	Wet Thermometer.	Relative Humidity.	Wet Thermometer.	Relative Humidity.	Direction.	Velocity.	Direction.	Velocity.	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.01	30.01	36.	49.	54.	34.	32.	64	41.	48.	SE	9	SE	11	0.00	0.00	5	A. St.	10	S. Cu.	
2	29.92	29.86	38	31	44	31	33	58	26	47	W	13	NW	12	.00	.00	10	S. Cu.	0	0	
3	29.71	29.71	25	38	40	25	21	49	31	42	W	20	W	12	.00	.00	5	A. St.	0	0	
4	29.66	30.01	33	26	36	24	28	51	23^5	69	E	11	N	18	.00	.00	5	A. St.	0	0	∞
5	30.04	30.01	26	31.	31	23	24	75	30^5	94	E	9	NW	6	T	.01	10	Nb.	10	Nb.	Ʈ $\equiv^2$ Δ^1
6	30.30	30.32	22	23	28	19	21,	86	22	86	NW	12	N	10	.50	.01	10	S. Cu.	10	Nb.	Δ^2 $\equiv^2$
7	30.12	30.09	27	25	30	19	26^5	94	24	87	NW	6	W	12	.60	.12	10	Nb.	10	S. Cu.	Δ^2 °
8	30.40	30.61	16	24	24	15	15	82	22	78	W	12	N	8	T	T	10	S. Cu.	10	Nb.	$\equiv^2$
9	30.59	30.40	22	26	27	21	21	86	25	87	SE	18	SE	12	T	.00	10	S. Cu.	10	S. Cu.	$\equiv^2$
10	30.25	30.08	30	35	38	24	29	89	35	100	S	9	SE	10	T	.82	10	Nb.	10	Nb.	≡
11	29.96	30.05	39	25	40	14	39	100	24,	87	W	2	NW	18	.22	T	FOGGY		10	Nb.	$\equiv^2$ Δ^0
12	30.58	30.57	8	18	20	7	7	77	16^5	75	NW	12	SE	5	.01	.00	0	0	0	0	
13	30.45	30.60	19	26	27	18	18	84	24	75	SE	12	NW	18	.00	.00	2	A. Cu.	0	0	
14	30.64	30.42	18	36	40	17	17,	84	34	82	SE	6	SE	12	.00	.00	0	0	0	0	$\equiv^0$
15	30.26	30.15	43	51	52	33	40^5	81	46	68	S	18	SE	10	.04	.00	10	S. Cu.	10	S. Cu.	$\equiv^0$
16	30.08	29.90	53	56	58	49	50,	81	55,	94	S	18	S	18	T	.25	10	S. Cu.	10	Nb.	
17	29.88	29.85	55	56	59	54	52^5	79	53^5	85	S	6	SE	12	.19	.00	10	S. Cu.	10	S. Cu.	$\equiv^0$
18	30.11	30.22	35	38	56	34	32	64	34	66	W	18	SE	6	.00	.00	0	0	0	0	⌓
19	30.06	29.87	36	58	63	34	33	73	54	77	SE	12	S	18	.00	T	8	A. St.	10	Cirr.	◡ ∞^0
20	29.82	30.35	34	21	57	20	34	100	20	85	N	12	NW	18	.97	.35	10	Nb.	10	St. Cu.	Δ^2
21	30.49	30.38	14	30	32	13	18,	81	27	67	NW	2	SE	15	.00	.00	SMOKY		0	0	Dense Smoke. $\sqcap^2$
22	30.81	30.07	25	32	33	25	24^5	94	32	100	SE	10	SE	12	.00	.15	FOGGY		10	Nb.	$\equiv^2$ $\sqcap^2$
23	29.81	30.05	43	40	46	32	42,	92	38	88	SW	3	NW	8	.69	.00	10	Nb.	10	S. Cu.	$\equiv^2$
24	30.14	30.11	30	40	41	29	28^5	83	36	68	N	8	NW	4	.00	.00	8	Ci. St.	0	0	$\equiv^2$ $\sqcap^2$ ∞^2
25	30.07	29.92	30	52	58	30	29	89	42	40	S	5	SW	4	.00	.00	2	A. St.	0	0	⊓ $\sqcap_2$ ≡
26	29.87	29.88	43	47	56	35	38	63	42,	66	SW	5	NW	20	.00	.00	2	A. St.	8	S. Cu.	
27	30.03	29.92	24	37	38	23	22	73	31^5	53	NW	12	S	5	.00	.00	2	A. St.	0	0	⌓ ◡ ∞^2
28	29.86	30.17	37	29	41	27	36	91	27	77	W	10	NW	10	.01	.00	10	Nb.	9	S. Cu.	
29	30.07	29.67	29	50	56	27	27	77	42	49	SE	12	SE	20	.00	.00	9	S. Cu.	0	0	
30	29.84	29.81	45	44	57	32	39	57	42	65	SE	12	W	20	.00	.04	2	A. St.	10	Nb.	⌓ ⊕
31	30.05	30.27	26	15	32	8	23	63	12	46	NW	9	NW	20	.01	.00	5	S. Cu.	0	0	
	30.11	30.11	31	36	42^7	25^7	29	76%	32	78%	SE	10	SE	12	3.14	1.75	5^6	S. Cu.	6	S. Cu.	MEAN.

FEBRUARY 1918.

Date.	Pressure.		Temperature.				Moisture.				Wind.				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum.	Wet.	Relative Humidity.	Wet.	Relative Humidity.	Direction.	Velocity.	Direction.	Velocity.	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.52	30.60	5	15	16	4	3	60	12	46	NW	12	N	6	0.00	0.00	1	S.Cu.	10	S.Cu.	
2	30.52	30.24	16	25	26	15	13	57	22	62	SE	9	SE	12	0.00	T	7	S.Cu.	10	Nb.	Snow
3	30.05	30.21	23	26	30	20	22	86	23	69	N	16	NW	7	0.30	0.25	10	S.Cu.	0	0	Snow
4	29.88	30.35	15	23	29	14	13	68	19	46	NE	8	N	5	0.00	0.00	3	Ci.Cu.	0	0	$\equiv^2$ and Smoky
5	30.42	30.34	9	13	15	8	7	65	11	61	N	7	W	8	0.00	0.00	10	Ci.Cu.	0	0	
6	30.38	30.38	8	24	25	7	6	64	20	47	W	5	W	6	0.00	0.00	1	Strat.	7	Ci.St.	
7	30.48	30.31	13	24	27	12	11	61	20	47	NW	10	W	7	0.00	0.00	0	0	0	0	
8	30.28	30.34	17	31	35	17	15	66	26	47	W	12	W	5	0.00	0.00	0	0	0	0	
9	30.32	30.29	26	34	36	25	21	57	29	52	SW	5	SE	9	0.00	0.00	10	S.Cu.	10	S.Cu.	Dense Smoke
10	30.20	30.05	33	37	38	32	33	90	37	100	SE	15	SE	8	0.00	T	10	S.Cu.	10	Nb.	$\equiv^2$ Snow
11	30.08	30.29	30	26	36	31	27	67	22	51	NW	18	NW	10	0.92	0.00	10	S.Cu.	0	0	
12	30.49	30.61	15	16	21	12	12	46	13	40	N	12	N	10	0.00	0.00	0	0	0	0	
13	30.55	30.32	10	29	30	10	9	56	24	44	SE	7	SE	8	0.00	0.00	0	0	0	0	
14	30.14	30.04	29	47	49	25	26	68	37	37	W	6	W	2	0.00	0.00	0	0	0	0	$\sqcap^1$ $\equiv^1$
15	29.88	29.96	37	45	54	36	33	65	40	64	S	8	NW	10	0.00	0.00	5	A.St.	5	Fr.Cu.	
16	30.01	29.98	33	53	55	32	32	90	44	47	SW	4	W	6	0.05	0.00	9	S.Cu.	9	Fr.Cu.	Δ^0 Lunar Halo
17	30.08	30.03	41	53	56	41	38	76	45	52	N	5	SE	9	0.00	0.00	0	0	0	0	$\equiv^2$ $\equiv^2$
18	29.95	29.81	48	61	68	41	40	77	48	85	SE	7	SE	18	0.00	0.00	0	0	0	0	$\equiv^2$ Warmest day on record.
19	29.87	29.82	51	63	68	50	46	68	52	46	SE	16	SE	12	0.00	0.00	8	A.St.	8	Fr.Cu.	
20	30.02	29.98	39	40	49	38	37	87	38	88	N	15	E	5	0.00	T	10	Cu.Nb.	10	Fr.Cu.	
21	29.86	29.60	42	56	56	38	40	88	53	82	NE	1	SE	12	T	0.29	10	Cu.Nb.	10	Fr.Cu.	☈ 1:35 P.⌒
22	29.89	30.08	31	32	40	26	27	58	27	54	W	20	W	12	0.00	0.00	10	S.Cu.	0	0	
23	30.26	30.20	22	22	25	20	19	58	21	85	NW	10	N	10	0.00	0.10	5	A.Str.	10	Nb.	Snow
24	30.30	30.27	13	25	27	12	12	90	21	49	NW	5	NW	7	0.05	0.00	0	0	0	0	Snow
25	30.26	29.98	22	37	37	21	19	65	31	58	SE	12	SE	20	0.00	T	8	A.Cu.	10	Nb.	Δ^2
26	29.75	29.56	41	38	53	34	37	72	37	96	SE	6	N	05	0.98	0.21	10	S.Cu.	10	S.Cu.	$\equiv^2$
27	29.68	29.85	33	28	34	25	32	95	27	88	NE	12	N	12	0.04	0.01	10	Nb.	10	Nb.	Snow, Δ^2
28	30.11	30.06	22	25	27	22	20	71	24	87	N	12	N	10	T.	0.15	10	S.Cu.	10	Nb.	Snow
	30.17	30.18	25^7	33^9	38	23^5	23^4	70%	28^9	59^9	SE	9	SE	8^8	0.54	1.01	5	S.Cu.	5	Fr.Cu.	Mean

MARCH 1918.

Date.	Pressure.		Temperature.				Moisture.				Wind.				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.B.M.	7.A.M.	7.B.M.	Maximum	Minimum	Wet.	Relative Humidity.	Wet.	Relative Humidity.	Direction.	Velocity.	Direction.	Velocity.	7.A.M.	7.B.M.	Amount.	Kind.	Amount	Kind.	
	in.	in.	°	°	°	°	°	%	°	%					in.	in.					
1	30.15	30.31	13	27	32	13	12^{5}	92	24	64	NW	10	W	22	0.41	T	8	Fr.Cu.	9	S.Cu.	Wind 33mi/hr.
2	30.53	30.34	5	30	30	4	3^{2}	52	24^{5}	41	W	20	SE	18	0.01	0.00	0	0	0	0	40mi/hr.
3	30.14	30.07	36	50	52	30	31	55	40	38	SE	11	S	8	0.00	0.00	10	A.Cu.	10	Str.	
4	30.03	30.24	39	34	45	31	36	75	30	62	N	12	N	8	0.00	T	10	Fr.Cu.	0	0	
5	30.15	30.08	28	35	46	25	27	88	31	62	S	5	NW	20	0.00	0.14	0	0	9	Fr.Cu.	Γ^{2} 40mi/hr.
6	30.36	30.40	16	27	29	16	13^{2}	51	22	41	NW	13	W	7	0.00	0.00	0	0	0	0	31mi/hr.
7	30.40	30.28	25	40	41	23	21^{5}	55	34	52	SE	12	SE	6	0.00	T	10	Str.	10	S.Cu.	$\equiv^{1}$
8	30.31	30.12	43	59	66	39	39	70	46	33	SW	7	SW	4	0.00	0.00	2	Str.	0	0	
9	30.12	30.13	51	50	62	43	42	45	45	67	SW	12	N	12	0.00	0.00	7	S.Cu.	9	S.Cu.	
10	30.04	30.02	40	41	45	36	38	83	40	92	NE	7	N	12	T	0.10	10	Cu.Nb.			
11	30.12	30.06	37	47	49	36	36	91	42	66	N	6	SE	12	0.01	0.00	9	S.Cu.	0	0	
12	30.03	29.89	39	58	62	39	37^{5}	88	50	56	SE	5	SE	20	0.00	0.00	9	Fr.Cu.	9	Fr.Cu.	$\equiv^{2}$ Max.vel 30m
13	29.83	29.87	52	58	59	50	50^{5}	90	55	83	SE	12	SE	13	0.00	0.39	10	S.Cu.	0	0	TS 1:45P.M.
14	29.80	29.54	53	41	63	35	43^{5}	44	34	46	SE	18	W	20	0.00	0.00	0	0	0	00	Max.vel. 42
15	29.64	30.02	29	24	34	24	27	77	21^{5}	67	W	12	NW	15	T	0.01	10	Cu.Nb.	10	Cu.Nb.	*all day
16	30.24	30.40	24	36	39	23	22	78	30^{5}	51	W	12	W	10	0.00	0.00	0	0	0	0	
17	30.57	30.41	27	53	59	27	25^{5}	76	41	31	SE	12	SE	18	0.00	0.00	0	0	0	0	
18	30.44	30.18	43	57	65	43	35^{5}	46	44	31	SE	12	SE	14	0.00	0.00	0	0	0	0	
19	30.07	29.72	43	60	66	43	38	63	54	68	SE	20	SE	18	0.00	0.00	0	0	10	Fr.Cu.	$\equiv^{0}$
20	29.84	29.69	38	48	58	38	36	83	43	66	W	12	E	7	0.00	T	10	S.Cu.	10	Nb.	TS 9:50P.M.
21	29.86	30.44	30	28	45	26	28^{5}	78	24	54	W	30	NW	12	1.41	0.00	10	S.Cu.	0	0	Cold Wave.M.vel50
22	30.68	30.43	22	40	41	22	19^{5}	65	35	60	E	5	SE	18	0.00	0.00	2	Ci.S	10	Cir.	
23	30.06	29.79	44	69	73	40	40^{5}	71	63	67	SE	18	SE	20	0.61	0.83	10	Fr.Cu.	10	Nb.	▲^{1} 2:45A.M.
24	29.79	29.80	58	44	72	44	50^{5}	84	44	100	S	7	NW	12	0.13	2.16	8	Ci.Cu.	10	Nb.	TS 4 during day.
25	29.81	29.94	42	35	42	34	41^{5}	96	34	91	NE	6	N	10	1.92	0.02	10	S.Cu.	10	Nb.	$\equiv^{0}$
26	30.04	30.05	32	25	38	25	30^{5}	84	24	87	N	12	N	18	T	1.00	10	Cu.Nb.	10	Nb.	10 in. Snow
27	30.32	30.48	24	29	30	24	22	78	25	55	NW	18	NW	6	0.07	0.00	10	Fr.Cu.	0	0	
28	30.46	30.25	35	44	47	24	32^{5}	68	38	56	SE	9	SE	15	0.00	0.00	0	0	0	0	
29	30.17	29.97	38	57	60	37	34^{5}	70	46	40	SE	10	SE	12	0.00	0.00	3	Cir.S.	9	S.Cu.	
30	29.91	29.74	51	69	75	49	44^{5}	59	55	39	S	5	SW	9	0.00	0.00	2	Ci.S.	0	0	
31	30.03	30.11	49	59	61	49	40^{5}	45	45	29	NW	12	NW	7	0.00	0.00	1	S.Cu.	0	0	Max. vel 31 mi.

APRIL 1918

Date	Pressure		Temperature.				Moisture.				Wind				Precipitation.		Clouds				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum	Minimum	Wet	Relative Humidity	Wet	Relative Humidity	Direction	Velocity	Direction	Velocity	7.A.M.	7.P.M.	Amount	Kind	Amount	Kind	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.19	30.04	50	63	67	48	44	61	50^5	40	S	4	SE	12	0.00	0.00	1	Cu.	0	0	
2	29.86	29.69	57	70	83	54	50_5	61	61	59	SE	9	SE	18	0.00	0.00	3	Ci.Cu.	2	A.Cu.	Max.Vel 30mi-
3	29.65	29.67	64	63	70	55	59^5	77	60	84	S	20	W	3	0.01	0.23	10	S.Cu.	10	Nb.	ꓘ Max Vel 36mi.
4	29.96	30.33	44	47	53	41	40^5	74	41	59	W	18	W	16	0.00	0.01	10	S.Cu.	9	S.Cu.	Max.Vel. 36mi
5	30.44	30.30	39	55	61	38	36^5	79	44	38	W	6	NE	4	0.00	0.00	0	0	0	0	≡¹ ∞¹
6	30.30	30.18	48	56	60	47	41_5	54	47^5	52	E	6	E	10	0.00	0.00	0	0	2	Ci.St.	
7	30.14	30.17	44	46	49	40	37^5	53	41	65	E	12	E	12	T	0.25	9	Nb.	10	S.Cu.	
8	30.07	29.94	40	43	46	40	40	100	42	92	E	14	SE	24	0.58	2.03	10	Nb.	10	Nb.	ꓘ Max.Vel 40mi
9	29.86	29.77	48	62	64	47	47	98	58	79	SE	12	SE	12	0.08	0.00	10	S.Cu.	10	Cu.Nb.	≡²
10	29.79	29.94	48	46	57	43	44	78	40	58	W	9	SW	18	0.02	0.00	10	S.Cu.	10	S.Cu.	Max.Vel.30mi.
11	29.99	30.08	41	42	45	39	38	78	38	69	W	12	W	10	0.00	T	10	S.Cu.	10	S.Cu.	
12	30.10	30.15	39	39	43	39	38	92	37	88	N	15	NW	12	0.06	0.02	10	Nb.	10	Nb.	
13	30.06	30.00	39	49	50	38	37	83	43	61	N	10	N	4	0.02	T	10	Nb.	9	S.Cu.	
14	30.01	29.96	44	59	65	41	40	71	48	42	NW	7	N	6	0.00	0.00	0	0	0	0	⊓²
15	30.05	29.98	42	60	64	40	38	69	48	39	N	6	N	8	0.00	0.00	0	0	0	0	
16	30.05	29.97	49	68	70	49	43^5	64	53	34	N	1	SE	4	0.00	0.00	0	0	0	0	Smoky all day.
17	30.02	29.89	57	76	84	54	48	50	59	34	SE	5	SE	11	0.00	0.00	0	0	0	0	≡¹
18	29.99	29.99	64	72	81	61	55	56	59	45	NW	4	N	12	0.00	0.00	3	Ci.S.	0	0	● ∞¹
19	30.20	30.22	53	62	67	53	49	75	48	33	N	10	NE	4	0.00	0.00	0	0	1	Cis.	◡
20	30.40	30.35	47	57	61	47	38	40	44	31	E	12	E	5	0.00	0.00	0	0	8	A.S.	
21	30.34	30.16	46	70	75	45	39^5	58	54	33	SE	16	SE	12	0.00	0.00	5	Cis.	0	0	
22	30.10	29.96	62	75	83	60	54_5	59	59	37	S	5	SE	18	0.00	0.00	10	Ci.Cu.	3	S.	Max.Vel 31mi.
23	29.98	29.86	63	71	78	62	55^5	62	58^5	46	SE	16	SE	15	0.00	0.00	3	Ci.Cu.	2	Cu.	∞² Max.Vel.40mi.
24	29.92	30.01	61	63	75	55	58	84	52	46	SE	12	W	12	0.15	0.02	9	Cu.	9	S.Cu.	
25	30.18	30.16	47	50	54	46	45	86	44^5	64	NW	8	N	2	0.15	0.12	10	Nb.	0	0	≡⁰
26	30.16	30.13	45	53	61	44	42^5	82	46	58	NW	4	S	3	0.00	T	7	S.Cu.	0	0	Ω² ꓘ Max Vel 30
27	30.11	30.10	46	51	53	46	40	59	43	59	NE	7	N	10	0.00	0.00	3	S.Cu.	0	0	
28	30.12	30.04	46	61	64	42	42	72	47	31	N	12	N	6	0.00	0.00	2	Ci.Cu.	0	0	
29	30.17	30.11	4	67	70	46	40^5	50	53	37	NE	6	SE	4	0.00	0.00	0	0	3	S.	
30	30.20	30.09	57	72	77	55	51	66	56	34	SE	6	SE	12	0.00	0.00	0	0	0	0	
	30.08	30.04	49	59	64	47	45	69	49	51	SE	9^4	SE	9^8	1.07	2.68	5	S.Cu.	3^7	S.Cu.	

MAY 1913

Date	Pressure		Temperature.				Moisture				Wind				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum	Minimum	Wet.	Relative Humidity	Wet	Relative Humidity	Direction	Velocity	Direction	Velocity	7.A.M.	7.P.M.	Amount	Kind.	Amount	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.14	29.99	61	77	82	58	53,	58	59^5	34	SE	5	SE	13	0.00	0.00	0	O	2	Str.	
2	30.06	29.93	66	77	83	62	55^5	51	60,	35	SE	8	SE	9	0.00	0.00	8	Ci.St.	4	Ci.St.	
3	29.98	29.92	69	75	81	67	59^5	57	58^5	35	SE	10	SE	12	0.00	0.00	7	A.St.	7	A.Cu.	Max.Vel 30mi.
4	30.05	30.07	64	72	74	62	60	79	61	53	SE	23	SE	20	0.21	0.13	9	Cu.Nb.	8	S.Cu.	
5	30.11	30.05	65	74	79	61	57	61	60	48	SE	12	SW	4	T	0.00	10	Nb.	3	S.Cu.	
6	30.26	30.24	53	62	68	53	49,	75	47	28	N	12	N	12	0.09	T	10	Nb.	0	O	
7	30.24	30.12	52	65	69	48	44^5	54	48	24	NE	3	E	2	0.00	0.00	0	O	0	O	
8	30.17	30.11	56	73	75	54	47	50	57	35	SE	12	SE	4	0.00	0.00	2	Ci.St.	2	Ci.Cu.	
9	30.22	30.38	60	57	75	52	54,	68	52	71	N	6	N	10	0.00	0.00	9	A.Cu.	2	Str.	
10	30.39	30.26	46	57	58	42	37^5	59	45	35	N	6	E	5	T	T	10	Nb.	8	A.St.	
11	30.24	30.06	46	60	65	45	40	58	48	40	SE	12	S	6	0.00	0.00	9	Str.	2	Ci.Str	
12	30.03	29.89	52	73	76	49	45	57	62,	53	SE	9	SE	7	0.00	0.00	9	St.Cu.	0	O	
13	29.94	29.73	62	81	87	58	59	84	65^5	41	S	6	SE	18	0.00	0.00	5	Ci.St.	2	Str.	Ω²
14	29.88	29.79	70	81	88	69	62,	64	64^5	39	S	8	SE	10	0.00	0.00	8	Ci.St.	2	St.Cu.	
15	29.80	29.86	72	78	81	67	64^5	67	63	57	S	10	W	10	0.00	T	5	St.Cu.	2	St.Cu.	● ∞
16	29.94	29.87	58	67	70	55	52^5	69	59^5	64	NE	4	SE	6	0.00	0.07	9	St.Cu.	0	O	T
17	29.93	29.97	57	70	73	56	57	100	59	51	SE	6	N	8	0.00	0.00	?	?	7	S.Cu.	K² Ω² ●
18	30.13	30.05	61	72	74	59	55	68	55	31	N	8	NE	3	0.25	0.00	10	St.Cu.	0	O	K
19	30.10	29.90	60	74	76	55	51	53	63	54	SE	10	SE	12	0.00	T	4	St.Cu.	8	ST.Cu.	
20	29.90	29.75	64	76	86	60	57	65	66	59	SE	13	SE	13	0.00	0.00	5	Ci.St.	3	St.Cu.	● Max.Vel 32.mi.
21	29.78	29.94	73	60	77	56	66^5	71	55,	73	S	9	NW	15	0.00	0.00	8	ST.Cu.	10	St.Cu.	
22	30.03	30.04	54	56	60	54	49,	70	49^5	63	NW	10	NW	10	0.00	0.00	9	St.Cu.	10	St.Cu.	
23	30.05	30.07	52	59	60	52	48^5	78	50	52	NW	6	N	6	0.00	0.00	10	St.Cu.	8	St.Cu.	
24	30.12	30.03	51	72	76	48	48^5	84	58,	42	NW	5	SW	4	0.00	0.00	0	O	0	O	≡¹ Ω¹
25	30.09	29.95	61	71	75	59	55	68	60^5	54	Calm.		SE	13	0.00	T	8	A.St.	7	St.Cu.	
26	29.82	29.88	61	68	76	58	60	94	56,	64	SE	13	N	20	0.45	0.28	10	Nb.	7	S.Cu.	T
27	30.03	29.97	53	74	76	52	51	87	59^5	41	N	13	NW	2	0.00	0.00	2	Fr.Cu.	0	O	
28	30.00	29.91	63	85	89	59	58,	74	64	30	W	8	S	5	0.00	0.00	1	Ci.St.	3	Ci.St.	
29	29.92	29.75	72	88	92	67	60^5	51	72	46	SW	5	SW	6	0.00	0.00	5	Ci.Cu.	4	CiSt.	
30	29.84	29.88	77	89	94	76	69	67	74,	49	W	11	W	3	0.00	0.00	5	CiSt.	2	St.Cu.	
31	29.97	29.87	76	89	93	74	67	62	73^5	49	SE	10	E	4	0.00	0.00	0	O	3	St.Cu.	Dist. T
	30.04	29.98	61	72	77	58	58	68	59	47	SE	8^7	SE	9	1.00	0.48	6	St.Cu.	3^7	St.Cu.	

JUNE 1913

Date.	Pressure.		Temperature				Moisture				Wind.				Precipitation		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum	Minimum	Wet.	Relative Humidity	Wet.	Relative Humidity	Direction	Velocity	Direction	Velocity	7.A.M.	7.P.M.	Amount	Kind.	Amount	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	29.93	29.91	75	75	94	70	67	64	65	58	W	10	N	18	0.00	T	4	Ci.St.	8	Nb.	Ꝁ Max.Vel 36mi.
2	29.98	29.87	72	84	89	67	67	77	67	40	E	8	N	2	0.00	0.00	1	Ci.St	6	Str.	∞
3	29.87	29.86	68	88	86	70	63	57	65	36	N	5	N	5	0.00	0.00	5	St.Cu.	6	Str.	
4	30.03	29.89	65	82	85	63	52	39	66	42	N	4	E	6	0.00	0.00	0	0	0	0	
5	30.07	29.96	68	76	88	68	68	76	69	63	SE	12	SE	4	0.00	1.05	10	A.St.	4	St.Cu.	Ꝁ Exc.Rain.
6	29.97	29.89	76	83	93	70	70	74	68	46	S	5	SE	6	0.00	0.00	7	Ci.St.	3	Ci.Cu.	
7	29.98	30.10	74	58	76	52	67	69	52	66	NW	8	NE	12	0.00	T	5	Ci.St.	7	St.Cu.	
8	30.22	30.18	50	68	70	49	45	67	51	32	N	12	NE	8	0.00	0.00	9	St.Cu.	5	Ci.St.	Min.Temp-Low Record.
9	30.35	30.32	51	66	70	48	44	56	49	25	NW	8	E	6	0.00	0.00	3	Ci.St.	2	Ci.St.	
10	30.46	30.38	52	72	74	49	45	57	51	18	E	7	E	8	0.00	0.00	0	0	0	0	Unusually low humidity
11	30.40	30.28	56	75	78	53	47	50	53	18	E	1	E	8	0.00	0.00	0	0	0	0	
12	30.28	30.12	61	80	83	57	51	49	56	18	E	1	S	3	0.00	0.00	0	0	0	0	
13	30.14	30.00	65	81	84	60	55	52	60	27	W	3	SE	7	0.00	0.00	0	0	0	0	
14	30.04	29.93	68	85	90	62	58	54	61	22	S	5	SW	7	0.00	0.00	1	Ci.St.	1	Ci.St.	
15	30.03	29.98	71	88	95	69	61	56	66	30	S	8	SW	7	0.00	0.00	6	Ci.Cu.	2	Ci.St.	
16	30.10	30.04	74	92	96	71	63	54	64	19	W	6	SW	4	0.00	0.00	4	Ci.St.	0	0	
17	30.13	30.04	77	93	98	73	66	55	67	23	W	3	W	3	0.00	0.00	0	0	0	0	
18	30.12	30.03	75	91	99	74	66	62	69	32	W	3	E	5	0.00	0.00	0	0	5	Fr.Cu.	
19	30.08	29.96	77	91	96	74	66	56	69	33	W	5	W	7	0.00	0.00	0	0	1	St.	
20	30.01	29.89	77	87	93	74	65	53	67	34	W	5	S	6	0.00	T	9	Fr.Cu.	3	St.Cu.	
21	29.92	29.88	80	75	97	74	68	54	69	74	W	7	N	10	0.00	0.01	4	Ci.Cu.	9	St.Cu.	Ꝁ
22	29.96	29.90	72	78	86	67	69	86	70	86	SE	4	SE	7	0.00	0.64	9	St.Cu.	10	Nb.	Ꝁ ▲°
23	29.88	29.80	71	82	86	69	68	86	74	69	SE	4	SE	20	0.94	0.02	7	Nb.	8	St.Cu.	Ꝁ
24	29.86	29.83	73	76	87	70	70	86	72	82	SE	3	SE	15	0.48	T	9	A.Cu.	8	Fr.Cu.	Ꝁ
25	29.85	29.84	77	85	90	75	71	74	72	52	S	7	SE	8	0.00	0.09	8	A.Cu.	8	Ci.St.	
26	29.99	29.94	78	89	93	73	68	65	73	46	SE	5	SE	8	0.00	0.00	3	Ci.St.	3	Ci.St.	
27	30.04	29.95	79	90	98	78	74	79	76	53	SE	4	N	3	0.00	0.00	1	Ci.St.	8	Ci.St.	
28	30.03	29.90	83	94	98	79	74	65	75	41	W	2	W	4	0.00	0.00	0	0	6	Ci.Cu.	
29	29.97	29.89	84	85	99	79	74	62	76	66	W	3	W	4	0.00	T	1	Ci.St	10	A.St.	Ꝁ Max.Vel 30mi.
30	29.97	29.87	80	95	98	78	74	75	75	38	W	5	SW	7	0.00	0.00	0	0	4	Ci.St.	
	30.06	29.98	71	82	89	67	63	64	66	43	W	5^2	SE	7	1.42	1.81	8^5	Ci.St.	4	Ci.St	

JULY 1913

Date.	Pressure		Temperature.				Moisture.				Wind				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum	Wet.	Relative Humidity.	Wet	Relative Humidity.	Direction	Velocity	Direction	Velocity	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	29.95	29.92	79	74	85	68	73	75	71	86	N	3	E	3	0.00	2.78	8	Ci.Cu	10	St.Cu.	☈ Max.Vel.40mi &
2	29.99	29.92	78	85	87	72	72	75	74.5	59	Calm		NE	3	0.00	0.00	7	?	3	Cu.	•² exc. Rain.
3	30.00	29.95	75	83	88	74	72	86	75	69	SE	6	SE	12	0.00	0.00	7	Ci.Cu	8	Ci.St.	☈
4	30.04	29.96	76	85	88	74	72	82	77	69	SE	6	SE	6	0.00	0.05	2	St.Cu.	1	Ci.St.	
5	30.03	29.99	79	92	96	77	71	68	69	30	W	12	NW	7	0.00	0.00	0	0	1	Cu.	
6	30.14	30.10	73	82	85	72	64	61	67	45	N	10	NE	6	0.00	0.00	1	Ci.St.	7	Ci.St.	
7	30.05	29.94	71	82	87	70	65	72	70	55	W	4	S	5	0.00	0.00	10	St.Cu.	5	Ci.St.	
8	29.98	29.85	75	86	91	71	71	82	72	50	S	4	SW	5	0.00	T	9	Ci.St.	9	St.Cu.	
9	29.91	29.83	73	92	95	70	69	82	70	32	SE	6	N	11	T	0.00	9	Ci.St.	1	Cu.	
10	30.02	29.89	70	82	84	67	61	51	68	33	E	5	NE	4	0.00	0.00	1	Ci.St.	0	0	
11	29.84	29.62	70	83	87	67	59.5	53	72	58	SE	10	SE	18	0.00	T	1	Ci.	9	Fr.Cu.	☈ Max.Vel.40mi.
12	29.87	29.86	71	84	87	67	67	81	69.5	49	W	10	SW	6	0.40	0.00	2	Ci.St.	4	Ci.St.	
13	29.93	29.87	74	88	93	70	70	82	76	57	S	6	S	12	0.00	0.00	7	Ci.Cu.	1	Ci.Cu.	
14	29.97	29.96	78	88	93	75	73	79	76	57	S	8	S	12	0.09	0.00	6	St.Cu.	6	St.Cu.	☈ ⌒⁎
15	30.07	30.08	78	83	85	76	72	75	76	69	SW	6	E	6	0.00	0.00	7	St.Cu.	8	Ci.St.	•
16	30.13	29.99	80	92	98	76	74	75	74	42	SW	4	SW	9	0.00	0.00	4	Ci.Cu.	5	Ci.St.	
17	29.99	29.90	80	95	100	78	70	61	82	31	W	13	W	8	0.00	0.00	0	0	5	Ci.St.	
18	29.94	29.87	81	90	101	78	71	61	76	52	W	9	NE	4	0.00	0.00	4	Ci.Cu.	5	Fr.Cu.	
19	30.07	29.96	67	84	86	65	65	90	65	35	N	8	NW	10	0.29	0.01	10	Nb.	0	0	☈ Max.Vel.40mi.
20	30.02	30.01	71	81	85	68	65	72	63	35	NW	3	N	8	0.00	0.00	7	St.Cu.	1	Cu.	
21	30.15	30.07	67	78	82	64	59	62	60	33	NE	5	N	4	0.00	0.00	0	0	0	0	
22	30.09	29.95	67	82	85	64	60	66	64	36	E	2	NE	4	0.00	0.00	0	0	3	Ci.Cu	
23	29.96	29.92	74	78	94	69	63	54	69.5	65	SW	12	W	6	0.00	T	1	Ci.St.	10	St.Cu.	☈
24	30.03	29.92	69	80	85	67	65	81	64	41	W	3	NE	5	0.15	0.00	10	St.Cu.	2	Ci.St.	
25	30.11	29.95	65	80	84	64	55.5	52	66	47	SE	12	E	6	0.00	0.00	4	Ci.St.	10	St.Cu.	
26	29.97	29.87	78	87	91	71	67	73	75	57	SE	5	SE	10	0.00	0.00	7	Ci.	5	St.Cu.	
27	29.99	29.99	80	77	90	69	72	68	72.5	81	SW	4	SE	5	0.00	0.77	5	Ci.Cu.	8	St.Cu.	☈ ▲ Max.Vel.40mi.
28	30.09	30.03	76	89	95	74	72	82	75	50	SW	8	S	4	0.00	0.00	3	Str.	5	St.Cu.	
29	30.06	30.00	80	86	100	77	74	75	75	60	SW	6	SE	12	0.00	0.00	0	0	6	A.St.	
30	30.04	30.00	83	88	97	77	76	69	72.5	62	SW	2	S	5	0.00	0.00	4	Ci.Cu.	10	Str.	
31	30.05	29.97	76	92	97	74	71	78	76	48	SW	4	S	5	0.00	0.00	6	Ci.St.	3	Ci.Cu.	☈
	30.01	29.94	74	87	90	71	68	72	71	50	SW	6	S	7	0.93	3.61	4	Ci.	5	St.Cu.	Mean

AUGUST 1913

Date.	Pressure		Temperature.				Moisture				Wind				Precipitation.		Clouds.				Miscellaneous Phenomena
							7.A.M.		7.A.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum	Wet.	Relative Humidity	Wet.	Relative Humidity	Direction.	Velocity	Direction	Velocity.	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.15	30.10	74	84	90	73	63^5	58	64	33	N	3	NE	4	T	0.00	6	St.Cu.	1	Ci.St.	
2	30.16	30.01	72	89	95	69	61^5	55	65_5	25	N	4	N	6	0.00	0.00	0	0	0	0	
3	30.07	29.94	72	93	98	69	62	57	67^5	27	NW	5	W	4	0.00	0.00	3	Ci.St.	1	Ci.St.	
4	30.00	29.95	76	85	94	73	65	55	66	39	N	6	NE	5	0.00	0.00	2	Ci.Cu.	8	St.Cu.	
5	30.05	29.92	72	87	91	68	59	45	68	40	E	2	S	5	0.00	0.00	0	0	4	A.Cu.	
6	29.91	29.85	78	95	102	77	64	46	71_5	32	SE	6	N	6	T	0.00	7	Ci.Cu.	2	St.Cu.	Max.Vel.30ml.
7	29.93	29.80	76	92	101	75	66	59	72^5	37	E	6	SE	17	0.00	T	1	A.Cu.	8	Cu.	☈
8	29.88	29.82	82	94	99	80	72	61	73	36	S	8	S	10	T	0.00	1	Ci.St.	4	Ci.St.	
9	29.95	29.92	81	88	95	78	73	68	73	48	S	7	SE	12	0.00	0.00	1	Ci.St.	1	Ci.St.	
10	30.01	29.96	78	85	89	75	71	71	73	56	S	6	SE	8	0.00	0.00	3	Ci.St.	2	A.St.	
11	30.03	29.98	75	87	90	72	71	82	75	57	Calm		E	5	0.00	0.00	9	St.Cu.	7	Fr.Cu.	
12	30.02	29.93	81	90	99	76	74	72	75	49	SE	5	SE	4	0.00	0.05	7	A.Cu.	9	Fr.Cu.	☈
13	30.01	29.99	83	80	88	74	74	65	73	72	W	6	SE	7	0.00	0.11	9	St.Cu.	6	A.St.	☈ M.Vel.40. ⌒ ●
14	30.03	29.89	78	93	97	75	72	75	73	37	S	4	SE	6	0.00	0.00	2	Ci.Cu.	3	Ci.Cu.	
15	29.95	29.87	81	91	100	77	73	68	74	44	S	3	SW	7	0.00	0.00	0	0	8	Fr.Cu.	
16	29.96	29.93	81	73	100	77	78	68	70^5	52	SE	3	SE	4	0.00	0.00	8	Ci.Cu.	9	St.Cu.	☈
17	30.01	29.96	79	84	97	77	72	71	73	59	SE	3	S	3	0.00	0.00	4	Ci.Cu.	5	A.St.	●
18	30.07	30.02	78	87	91	75	73	79	76	60	Calm		NE	3	0.00	0.00	7	Ci.St.	9	Fr.Cu.	∞ T Dense Smoke
19	30.08	30.08	77	77	88	70	72	79	73	88	N	3	NW	4	0.00	1.46	9	M.Cu.	7	St.Cu.	☈ 30ml.-all B.M.
20	30.11	30.03	74	82	93	71	71	86	73	65	NW	3	E	4	0.00	0.00	3	Ci.Cu.	4	Ci.St.	☈ ∞
21	30.06	29.95	76	81	95	74	73	87	73	68	SE	2	S	5	0.00	T	0	0	9	Cu.Nb.	☈
22	30.00	29.99	70	77	83	69	61	59	62	42	N	13	N	6	0.03	0.00	0	0	0	0	
23	30.03	29.99	64	79	83	61	59	74	63	40	N	3	N	3	0.00	0.00	0	0	1	Ci.St.	
24	30.03	30.03	69	81	85	64	62	67	63	35	Calm		E	4	0.00	0.00	0	0	0	0	
25	30.06	29.97	68	81	85	65	61	67	63	35	E	4	SE	9	0.00	0.00	0	0	0	0	
26	29.97	29.91	71	87	95	68	61	54	66	32	S	4	SE	10	0.00	0.00	0	0	2	Fr.Cu.	
27	30.03	29.99	72	92	97	71	64	65	74	42	SE	7	W	2	0.00	0.00	9	St.Cu.	?	?	
28	30.01	29.94	79	88	101	77	67	53	67	32	SW	5	N	20	0.00	T	8	St.Cu.	4	Ci.St.	Max.Vel.31ml.
29	30.01	29.87	68	83	88	66	56	46	58	18	NW	4	NW	7	0.00	0.00	1	Ci.St.	0	0	
30	29.88	29.88	71	86	93	68	57	46	61	21	SE	4	E	6	0.00	0.00	1	Ci.St.	5	Ci.St.	
31	29.91	29.91	78	88	98	71	59	42	62	20	SE	3	SE	18	0.00	0.00	9	St.Cu.	3	Ci.St.	
	30.02	29.95	75	86	93^6	72^5	67	64	69	43	SE	5	SE	7	0.08	1.62	3	Ci.	4	Ci.	Mean.

SEPTEMBER 1913.

Date.	Pressure		Temperature				Moisture				Wind				Precipi-tation		Clouds				Miscellaneous Phenomena
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.PM.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum.	Wet.	Relative Humidity.	Wet.	Relative Humidity.	Direction.	Velocity	Direction.	Velocity.	7.A.M.	7.P.M.	Amount.	Kind	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in					
1	30.03	29.99	76	92	99	74	64	51	71_5	35	SE	8	SE	12	0.00	0.00	1	Ci.Cu.	0	0	
2	30.13	30.04	79	92	99	77	68	57	70^5	33	SE	6	SE	6	0.00	0.00	0	0	0	0	
3	30.09	29.96	79	95	101	78	69	60	70	27	SW	2	Calm		0.00	0.00	0	0		Ci.	∞
4	30.00	29.91	78	92	100	77	69	63	71_5	35	NE	3	N	3	0.00	0.00	0	0	0	0	
5	29.99	29.94	71	88	93	60	67	81	70^5	43	NE	3	E	9	0.00	0.00	0	0	0	0	
6	30.04	30.01	74	85	90	73	68	74	71_5	49	SE	5	SE	6	0.00	0.00	1	Ci.Cu.	3	Ci.Cu.	
7	30.14	30.10	76	84	88	75	69	70	71^5	54	SE	5	SE	7	0.00	0.00	8	St.Cu.	3	Ci.St.	
8	30.15	30.18	77	74	91	71	72	78	70	82	Calm		N	6	0.00	0.06	10	St.Cu.	10	Nb.	☈
9	30.20	30.18	68	79	83	67	63^5	79	65	46	E	8	E	6	0.02	0.00	10	St.Cu.	0	0	
10	30.22	30.10	64	84	88	63	54^5	58	64	32	E	10	SE	6	0.00	0.00	0	0	1	Ci.	
11	30.12	30.08	70	70	88	67	66^5	83	68	90	S	2	NW	6	0.00	0.10	7	Ci.St.	10	Nb.	☈
12	30.06	30.15	65	65	67	60	64	95	57	61	NE	5	N	5	1.90	0.16	10	Nb.	9	St.Cu.	●
13	30.23	30.15	55	65	70	53	49	70	54_5	48	NE	7	E	4	0.00	0.00	9	A.St.	2	A.St.	
14	30.15	30.07	54	68	72	53	48	64	54^5	40	E	4	E	5	0.00	0.00	9	Ci.St.	5	Ci.St.	●
15	30.10	29.99	56	65	67	56	55	94	63^5	92	E	5	E	10	0.35	0.31	10	Nb.	10	Nb.	
16	29.99	30.05	67	70	72	64	65^5	92	67	86	SE	9	S	7	0.28	0.48	9	Cu.Nb.	9	St.Cu.	☈
17	30.08	30.01	66	69	80	62	65^5	97	64	76	S	2	SE	12	0.01	0.03	10	St.Cu.	10	Nb.	≡°
18	29.98	29.88	63	67	70	61	61	89	64	85	N	3	N	4	0.49	0.05	10	St.Cu.	10	St.Cu.	☈ ∩^{2}
19	29.84	29.70	64	72	76	62	62	90	65_5	69	E	2	SE	10	0.00	0.00	10	St.Cu.	4	Fr.Cu.	
20	29.75	29.81	56	54	66	49	52	76	48^5	67	NW	25	W	6	0.25	0.00	9	Fr.Cu.	10	St.Cu.	
21	29.91	29.98	45	54	57	44	40	64	43	37	NW	12	NW	5	0.00	0.00	1	A.St.	0	0	
22	30.04	30.03	42	56	60	40	37	63	48	55	N	2	E	7	0.00	0.00	0	0	0	0	Lowest Min. 1885.
23	30.10	30.05	50	72	78	48	47	80	59	45	SE	15	SE	12	0.00	0.00	7	Ci.St.	3	St.Cu.	Max.Vel.30mi.
24	30.17	30.08	59	71	79	58	55	78	60	52	SE	7	SE	12	0.00	0.00	7	Ci.St.	1	Ci.St.	●
25	30.09	30.12	59	56	75	51	55	78	55	94	SE	8	NW	10	0.00	0.08	9	A.St.	10	Nb.	
26	30.22	30.22	51	55	57	50	48	81	46	49	N	12	N	8	0.36	0.00	10	St.Cu.	3	St.Cu.	
27	30.28	30.18	48	64	66	47	46	86	52	48	NE	2	NE	5	0.00	0.00	9	Ci.St.	5	Ci.Cu.	⌓^{2}
28	30.07	29.96	58	65	68	57	53	72	64	95	SE	10	SE	12	0.01	0.19	10	NB.	10	Nb.	
29	29.98	29.90	61	73	77	60	61	100	64	61	NW	3	SE	5	0.08	0.00	0	0	0	0	⌓^{2}
30	30.00	29.96	60	69	76	60	59	94	60	59	W	5	W	9	0.00	0.00	0	0	0	0	
	30.07	30.03	63	72	78^4	60^8	58	77	62	58	SE	6	SE	7	3.97	1.41	6	St.Cu.	4	St.Cu.	Mean.

OCTOBER 1918.

Date	Pressure		Temperature				Moisture				Wind.				Precipitation.		Clouds				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum	Minimum	Wet.	Relative Humidity.	Wet.	Relative Humidity.	Direction	Velocity	Direction.	Velocity	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
1	30.06	29.99	56	70	76	56	54	88	61	59	NW	10	W	6	0.00	0.00	0	0	0	0	
2	29.95	29.93	57	69	77	57	55	88	54	35	NW	7	NW	7	0.00	0.00	0	0	0	0	
3	30.00	29.92	52	72	78	52	48	75	58	43	W	2	SE	8	0.00	0.00	0	0	0	0	
4	29.94	29.87	58	73	79	57	54	77	60	46	SE	7	SE	14	0.00	0.00	3	Ci.St.	1	St.Cu.	Max.Vel.30mi.
5	29.89	29.98	63	72	76	63	60	84	68	82	SE	6	SE	7	0.06	0.00	10	Nb.	0	0	
6	30.04	30.09	65	76	82	65	65	100	68	66	SE	8	SE	7	0.00	0.00	7	?	1	Cu.	≡²
7	30.02	29.95	67	73	74	67	66	95	69^{5}	88	SE	2	N	2	0.15	0.17	10	Nb.	10	St.Cu.	⛈ Δ²
8	29.95	29.91	67	70	75	65	65	90	64	72	SE	6	SE	4	0.02	0.38	10	Cu.Nb.	0	0	
9	29.95	29.88	63	73	78	62	62	95	69	82	SE	6	SE	10	0.00	0.00	10	St.Cu.	10	Ci.	∞
10	29.84	29.77	70	67	82	64	67	86	65	90	SE	12	S	7	0.00	0.16	2	A.Cu.	10	Nb.	⛈
11	30.18	30.20	47	59	63	47	48	72	48	42	NW	12	W	2	0.09	0.00	1	Ci.Cu.	0	0	
12	30.21	30.19	52	69	75	50	45	57	59	55	W	6	W	3	0.00	0.00	0	0	1	Ci.St.	●
13	30.25	30.18	56	70	79	54	52	76	59	51	S	3	SE	10	0.00	0.00	0	0	0	0	●
14	30.20	30.07	50	60	76	58	53	63	57	50	SE	10	SE	10	0.00	0.00	9	A.St.	0	0	
15	30.10	30.05	59	68	76	58	54	72	61	67	SW	4	N	6	0.00	0.00	7	St.Cu.	8	Ci.Cu.	
16	30.05	29.96	59	68	73	59	57	89	62	71	Calm.		SE	10	0.00	T	9	St.Cu.	10	Nb.	
17	29.93	30.06	53	50	63	46	52	94	48	87	W	16	NW	10	0.70	0.00	10	St.Cu.	10	St.Cu.	
18	30.16	30.11	44	51	55	43	42	85	44	56	N	7	N	6	0.02	0.00	7	St.Cu.	9	St.Cu.	
19	29.99	29.77	42	48	52	41	39	77	42	60	N	1	N	9	0.00	T	10	Ci.St.	10	Nb.	
20	29.76	29.93	33	39	40	32	32^{8}	95	31	35	NW	20	W	15	0.14	0.02	10	Nb.	9	Fr.Cu.	Max.Vel.50mi. First Snow.
21	30.10	30.06	30	40	42	30	27	67	34	52	NW	7	SE	12	0.00	0.00	0	0	10	St.Cu.	⛈ Δ²
22	29.92	29.95	41	39	46	36	39	84	38^{6}	96	NE	3	N	12	0.01	1.45	9	Cu.Nb.	10	Nb.	▽
23	30.08	30.01	37	47	50	35	36	91	43	72	N	10	N	6	0.31	0.00	10	St.Cu.	9	Fr.Cu.	≡¹
24	29.94	29.93	42	58	61	42	40^{5}	88	47	41	N	10	NW	3	0.00	0.00	9	St.Cu.	0	0	●²
25	30.03	29.97	46	59	65	45	46^{5}	82	50	52	NW	4	SE	10	0.00	0.00	0	0	0	0	⊔²
26	29.93	30.02	50	40	57	36	47	80	39	92	SE	3	NW	13	0.00	0.02	1	St.	10	Nb.	Δ².
27	29.82	29.85	34	35	35	32	34	100	34	91	N	20	NW	14	0.84	0.60	10	Nb.	10	Nb.	
28	30.04	30.00	34	46	50	32	33	90	42	72	W	4	SE	10	T	0.00	9	St.Cu.	9	St.Cu.	Killing Frost
29	30.09	30.24	28	32	37	27	27	88	30	79	W	15	W	12	0.02	0.00	10	St.Cu.	10	St.Cu.	C.W.
30	30.42	30.50	30	40	44	30	29	89	34	52	W	6	NW	6	0.00	0.00	0	0	0	0	
31	30.67	30.65	29	39	42	28	28	88	31	35	N	4	N	4	0.00	0.00	0	0	0	0	≡² ⊓²
	30.05	30.03	49	57^{4}	63^{2}	47^{4}	46^{7}	84	50^{6}	63	SE	7	SE	8	2.16	2.86	5	St.Cu.	4^{5}	St.Cu.	Mean

NOVEMBER 1918.

Date.	Pressure		Temperature				Moisture				Wind				Precipitation.		Clouds.				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M		7.P.M				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum	Minimum	Wet	Relative Humidity	Wet.	Relative Humidity.	Direction.	Velocity	Direction	Velocity.	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.65	30.48	30	42	46	30	28	78	34	40	N	8	SE	6	0.00	0.00	0	0	0	0	$\sqcap^{2}$ $\equiv^{0}$
2	30.43	30.27	40	51	59	39	35,	60	44,	56	SE	6	SE	12	0.00	0.00	9	St.Cu.	0	0	⊕
3	30.26	30.22	50	60	64	48	42^{5}	52	50^{5}	50	S	6	W	5	0.00	0.00	10	St.Cu.	9	St.Cu.	$\equiv^{1}$
4	30.38	30.38	42	51	57	42	40	83	42,	45	N	4	N	4	0.00	0.00	0	0	0	0	
5	30.39	30.28	39	52	55	39	36	75	44^{5}	54	SE	3	SE	4	0.00	0.00	0.	0	0	0	
6	30.18	29.93	40	60	68	40	38	83	51	53	SE	8	SE	18	0.00	0.00	9	Ci.St.	0	0	
7	29.84	29.80	56	55	67	48	53	82	50,	70	SE	12	W	15	0.00	0.01	9	St.Cu.	5	Fr.Cu.	
8	29.95	30.05	41	39	47	34	36	61	30^{5}	31	W	25	NW	18	0.02	0.00	10	St.Cu.	9	Fr.Cu.	
9	30.08	29.97	28	38	42	28	25	65	32	50	NW	12	NW	12	0.00	0.00	0	0	0	0	
10	29.98	30.10	29	33	36	28	25	55	27	41	NW	24	NW	6	0.00	0.00	8	St.Cu.	0	0	
11	30.25	30.12	27	43	46	26	24	64	35	42	W	3	SE	15	0.00	0.00	8	Ci.St.	8	Ci.St.	● ∞
12	30.02	29.96	48	67	73	43	42	60	58	58	SE	12	S	11	0.00	0.00	3	St.Cu.	8	St.Cu.	
13	30.06	30.03	60	66	69	57	55	73	60	71	S	7	S	9	0.00	0.00	9	St.Cu.	10	St.Cu.	
14	30.22	30.24	48	45	54	45	47	93	44,	93	N	4	NE	7	0.62	0.88	10	Nb.	10	Nb.	⛈ Δ
15	30.10	30.08	48	44	50	42	47	93	42^{5}	89	N	4	N	6	0.13	0.02	10	Nb.	10	St.Cu.	$\equiv^{2}$
16	30.11	30.17	42	46	48	41	41	92	43	79	NW	6	W	8	0.23	0.00	10	St.Cu.	0	0	
17	30.19	30.08	39	53	54	38	38	92	48	69	S	6	S	11	0.00	T	0	0	8	Fr.Cu.	$⌓^{2}$
18	30.06	29.98	53	62	70	51	51	87	59	84	SE	8	SE	12	0.00	0.00	8	St.Cu.	0	0	∞
19	29.89	29.91	61	65	73	61	58	84	61	80	SE	12	SE	14	0.00	0.00	9	St.Cu.	0	0	
20	29.96	29.94	62	67	73	61	59	84	60	66	S	9	SE	18	0.00	0.00	7	St.Cu.	0	0	
21	29.90	30.00	62	68	76	60	57	74	62	71	S	18	S	10	0.00	0.00	1	A.St.	0	0	
22	30.04	30.10	65	64	73	51	62	85	61,	84	S	14	W	10	0.00	0.20	8	Ci.St.	9	Fr.Cu.	
23	30.40	30.42	44	49	53	43	38	56	38^{5}	34	N	8	N	4	0.00	0.00	9	St.Cu.	0	0	
24	30.50	30.46	39	51	54	39	35	67	40	34	W	4	SE	2	0.00	0.00	0	0	0	0	Dense Smoke
25	30.37	30.18	46	46	51	45	38	45	41	65	SE	12	SE	10	0.00	0.04	10	St.Cu.	10	Nb.	
26	30.16	30.13	47	55	59	46	45,	86	48	59	SE	8	SE	10	0.13	0.00	10	St.Cu.	5	St.Cu.	⛈ $⌓^{2}$ $\equiv^{2}$
27	30.17	30.10	54	60	64	54	52^{5}	91	58	89	Calm		SE	7	0.00	0.02	?	?	10	Nb.	⛈ $\equiv^{2}$
28	30.11	30.08	55	59	61	55	55,	100	58	94	SE	6	SE	10	0.14	0.08	?	?	10	Nb.	
29	30.07	30.08	57	61	63	56	56^{5}	97	59	89	SE	6	SE	6	0.50	T	10	St.Cu.	10	Nb.	⛈
30	29.87	29.97	59	56	66	52	58	94	54	88	SE	20	SE	4	0.13	0.08	10	Nb.	0	0	
	30.15	30.11	47	53^{6}	59	44^{7}	43^{9}	77	47^{6}	64	SE	8^{6}	SE	9	1.90	1.27	6^{8}	St.Cu.	4^{8}	Cu.	Mean.

DECEMBER 1918.

Date.	Pressure		Temperature				Moisture				Wind				Precipitation.		Clouds				Miscellaneous Phenomena.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Maximum.	Minimum.	Wet.	Relative Humidity.	Wet.	Relative Humidity.	Direction	Velocity.	Direction.	Velocity.	7.A.M.	7.P.M.	Amount.	Kind.	Amount.	Kind.	
	in.	in.	°	°	°	°	°	%	°	%		mi		mi	in.	in.					
1	30.09	30.21	51	57	59	50	49	87	54	82	W	4	W	3	0.00	0.00	0	0	10	St.Cu.	≡¹ ≡² Dense Smoke.
2	30.32	30.38	54	57	60	53	53	94	54	82	Calm		S	2	0.00	0.00	10	St.Cu.	0	0	
3	30.25	30.28	54	56	58	53	53	94	54	88	E	1	NE	4	0.00	T	10	St.Cu.	10	St.Cu.	
4	30.31	30.13	52	48	52	48	50	87	46^{5}	90	NE	8	E	4	0.00	0.00	10	Fr.Cu.	10	St.Cu.	
5	30.01	29.83	47	53	53	45	46	93	49	75	SE	6	E	7	0.00	0.04	10	St.Cu.	10	Nb.	
6	29.75	29.79	52	55	60	51	51^{5}	97	46	49	SE	12	W	2	0.10	T	9	St.Cu.	10	St.Cu.	⊖
7	29.98	30.29	35	27	50	23	31	63	23	52	NW	36	NW	28	T	0.00	7	St.Cu.	0	0	
8	30.54	30.56	22	32	34	22	19	58	27	49	NW	8	NW	3	0.00	0.00	0	0	0	0	⊓²
9	30.57	30.48	25	40	44	25	23	74	32	37	W	8	SW	3	0.00	0.00	0	0	0	0	
10	30.27	30.28	33	43	48	32	30	70	39	70	W	12	NW	7	0.00	0.00	0	0	00	0	
11	30.38	30.34	34	47	51	33	33	90	39	46	NW	8	SE	6	0.00	0.00	0	0	0	0	⊓²
12	30.36	30.30	37	50	57	36	33^{5}	69	43	55	S	8	SE	7	0.00	0.00	0	0	0	0	
13	30.30	30.22	41	52	56	39	35	54	44	51	S	3	SE	5	0.00	0.00	2	Ci.St.	10	A.St.	
14	30.20	30.24	45	51	54	41	41	71	45	62	S	8	W	3	0.00	0.00	10	St.Cu.	0	0	
15	30.34	30.30	41	43	44	39	40^{5}	96	41	85	W	4	SW	4	T	T	10	St.Cu.	7	Fr.Cu.	◗
16	30.28	30.21	35	43	48	34	35	100	41	85	S	2	Calm		0.00	0.00	?	?	?	?	≡² ◠ ∞
17	30.12	30.08	43	46	49	40	42	92	45^{5}	93	S	1	NW	5	0.11	0.01	10	Nb.	9	St.Cu.	
18	30.21	30.23	32	41	44	32	30^{5}	84	35^{5}	57	N	4	Calm		0.00	0.00	0	0	0	0	≡² ⊓ ∞
19	30.19	30.01	32	41	44	32	31	89	36^{5}	65	SE	5	SE	6	0.00	0.00	0	0	0	0	
20	29.86	29.82	41	42	49	26	37	69	38	69	SE	11	W	12	0.01	0.11	10	Cu.Nb.	10	Cu.Nb.	
21	30.09	30.21	31	34	38	29	30	89	30	62	N	9	NW	5	0.10	0.00	10	St.Cu.	0	0	• ⊓² ∞
22	30.28	29.96	31	35	36	28	29	78	33	81	E	12	E	5	0.00	T	10	St.Cu.	10	Cu.Nb.	
23	29.91	30.08	32	34	35	32	31^{5}	95	32	81	W	12	W	6	0.24	0.00	10	St.Cu.	10	St.Cu.	Dense Smoke
24	30.10	30.05	34	36	36	33	32	81	34	82	SE	6	E	4	0.00	0.00	10	St.Cu.	10	St.Cu.	
25	29.87	29.99	32	30	33	29	32	100	29^{5}	94	N	15	NW	18	0.48	0.95	10	Nb.	10	Nb.	
26	30.18	30.29	29	30	30	28	28	88	27	67	N	6	N	3	0.10	0.00	10	St.Cu.	10	St.Cu.	
27	30.35	30.31	28	30	30	28	25^{5}	71	27^{5}	78	SE	8	E	9	0.00	0.00	10	St.Cu.	10	St.Cu.	
28	30.32	30.31	30	32	34	29	28^{5}	88	29^{5}	74	SE	6	E	3	T	0.00	10	St.Cu.	10	St.Cu.	
29	30.29	30.22	30	30	32	29	28^{5}	83	28	78	E	4	E	6	0.00	0.00	10	St.Cu.	10	St.Cu.	Dense Smoke
30	30.24	30.14	30	30	31	29	29	89	28^{5}	83	N	3	E	9	0.00	0.00	10	St.Cu.	10	St.Cu.	
31	30.00	30.11	30	30	31	29	29	89	27^{5}	78	NW	5	NE	6	0.00	0.00	10	St.Cu.	10	St.Cu.	
	30.20	30.13	37	41	44^{5}	35	35	83	37	71	SE	7	NW	6	1.14	1.15	6^{7}	St.Cu.	6	St.Cu.	Mean.

MEAN MONTHLY AND ANNUAL SUMMARIES 1918.

	Pressure		Temperature				Moisture				Wind				Precipitation.		Clouds				MEAN ANNUAL.—.
							7.A.M.		7.P.M.		7.A.M.		7.P.M.				7.A.M.		7.P.M.		
	7.A.M.	7.P.M.	7.A.M.	7.P.M.	Mean Maximum	Mean Minimum.	Wet Bulb	Relative Humidity	Wet Bulb.	Relative Humidity	Direction	Velocity	Direction	Velocity	7.A.M.	7.P.M.	Amount	Kind	Amount	Kind	
	in.	in.	°	°	°	°	°	%	°	%					in.	in.					
n	30.11	30.11	31	36	42^7	25^7	29	78	32	73	SE	10	SE	12	3.14	1.75	5^6	St.Cu.	6	St.Cu	Pressure: 30.06 Relative Humidity 65% Direction SE Velocity 8.2mi Clouds. Amount 47% Kinds St.Cu. Total Precipitation 45.86in
b	30.17	30.12	25^7	33^9	38	23^5	28^4	70	28^3	59^6	SE	9	SE	8^8	0.54	1.01	5	St.Cu	5	Fr.Cu.	
r.	30.11	30.07	35	44	51	32	31^8	70	38	58	SE	11^7	SE	13	4.32	4.65	5	St.Cu.	4^3	Nb.	
r	30.08	30.04	49	59	64	47	45	69	49	51	SE	9^4	SE	9^8	1.07	2.68	5	St.Cu.	3^7	St.Cu.	
y	30.04	29.98	61	73	77	58	58	68	59	47	SE	8^7	SE	9	1.00	0.42	6	St.Cu.	3^7	St.Cu.	
ne	30.06	29.98	71	82	89	67	68	64	66	43	W	5^3	SE	7	1.42	1.81	3^5	Ci.St.	4	Ci.St.	
l	30.01	29.94	74	87	90	71	68	72	71	50	SW	6^6	S	7	0.93	3.61	4	Ci.	5	St.Cu.	
g	30.02	29.95	75	86	93^4	72^2	67	64	69	43	SE	5	SE	7	0.03	1.62	3	Ci	4	Ci.	
p	30.07	30.02	63	72	78	60^8	58	77	62	58	SE	6	SE	7	3.97	1.41	6	St.Cu.	4	St.Cu.	
t	30.05	30.03	49	57^4	63^2	47^4	46^7	84	50^6	63	SE	7	SE	8	2.16	2.86	5	St.Cu.	4^6	St.Cu.	
v	30.15	30.11	47	53^6	59	44^7	43^9	77	47^8	64	SE	8^6	SE	9^3	1.90	1.27	6^7	St.Cu.	4^3	St.Cu.	
c	30.20	30.18	37	41	44^5	35	35	83	37	71	SE	7	NW	6	1.14	1.15	6^7	St.Cu.	6	St.Cu.	
	30.08	30.04	51^8	60^8	65^8	48^7	47^4	73	50^8	56^7	SE	7^6	SE	8^6	21^{62}	24^{24}	5	St.Cu.	4^8	St.Cu.	Annual.

DAILY MINIMUM TEMPERATURE 1918.

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	34	4	13	48	58	70	68	73	74	56	30	50		Lowest of the year +4° on February 1st and on March 2nd. On 86 days the minimum was 32° or below. The minimum on June 9th this year and in 1977 the lowest for the day since 1836. September 22 the lowest minimum on record for that day
2	31	15	4	54	62	67	72	69	77	57	39	53		
3	25	20	30	55	67	70	74	69	78	52	48	53		
4	24	14	31	41	62	63	74	73	77	57	42	48		
5	23	8	25	38	61	68	77	68	69	63	39	45		
6	19	7	16	47	53	70	72	77	73	65	40	51		
7	19	12	23	40	48	52	70	75	75	67	48	23		
8	15	17	39	40	54	49	71	80	71	65	34	22		
9	21	25	43	47	52	48	70	78	67	62	28	25		
10	24	32	36	43	42	49	67	75	63	64	28	32		
11	14	21	36	39	45	53	67	72	67	47	26	33		
12	7	12	39	38	49	57	67	78	60	50	43	36		
13	18	10	50	38	58	60	70	74	53	54	57	39		
14	17	25	35	41	69	62	75	75	53	58	45	41		
15	33	36	24	40	67	69	76	77	56	58	42	39		
16	49	32	23	49	55	71	76	77	64	59	41	34		
17	54	41	27	54	56	73	78	77	62	46	38	40		
18	34	41	43	61	59	74	78	75	61	43	51	32		
19	34	50	43	53	55	74	65	70	62	41	61	32		
20	20	38	38	47	60	74	68	71	49	32	61	36		
21	13	38	26	45	56	74	64	74	44	30	60	29		
22	25	26	22	60	54	67	64	69	40	36	51	28		
23	32	20	40	62	52	69	69	61	48	35	43	32		
24	29	12	44	55	48	70	67	64	58	42	39	33		
25	30	21	34	46	59	75	64	65	51	45	45	29		
26	35	34	25	44	58	73	71	68	50	36	46	28		
27	23	25	24	46	52	78	69	71	47	32	54	28		
28	27	22	24	42	59	79	74	77	57	32	55	29		
29	27		37	46	67	79	77	66	60	27	56	29		
30	32		49	55	76	78	77	68	60	30	52	29		
31	8		49		74		74	71		28		29		
	26	24	32	47	58	67	71^1	72^2	60^8	47^4	44^7	35		Mean Monthly

DAILY MAXIMUM TEMPERATURE 1918.

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	54	16	32	67	82	94	85	90	99	76	46	59		
2	44	26	30	83	83	89	87	95	99	77	59	60		There were 29 days with maximum temperature of 32° or below, and 54 days with 90° or above.
3	40	30	52	70	81	86	88	98	101	78	64	58		
4	36	29	45	53	74	85	88	94	100	79	57	52		
5	31	15	46	61	79	88	96	91	93	76	55	53		
6	28	25	29	60	68	93	85	102	90	82	68	60		
7	30	27	41	49	69	76	87	101	88	74	67	50		Of the latter 23 days occurred in August, 15 in July and 16 in June
8	24	35	66	46	75	70	91	99	91	75	47	34		
9	27	36	62	64	75	70	95	95	83	78	42	44		
10	38	38	45	57	58	74	84	89	88	82	36	48		
11	40	36	49	45	65	78	87	90	88	63	46	51		
12	20	21	62	43	76	83	87	99	67	75	73	57		February 18th had the highest maximum for that day on record (1836).
13	37	30	59	50	87	84	93	88	70	79	69	56		
14	40	49	63	65	88	90	93	97	72	76	54	54		
15	52	54	34	64	81	95	85	100	67	76	50	44		
16	58	55	39	70	70	96	98	100	72	73	48	48		November 21st also had the highest temperature for the day on record.
17	59	56	59	84	76	98	100	97	80	63	54	49		
18	56	68	65	81	74	99	101	91	70	55	70	44		
19	63	68	66	67	76	98	86	88	76	52	73	44		
20	57	49	58	61	86	93	85	93	66	40	73	49		
21	32	56	45	75	77	97	82	95	57	42	76	38		
22	33	40	41	83	60	86	85	83	60	46	73	36		
23	46	25	72	78	60	86	94	83	78	50	53	35		
24	41	27	72	75	76	87	85	85	79	61	54	36		
25	58	37	42	54	75	90	84	85	75	65	51	33		
26	56	53	33	61	76	93	91	95	57	57	59	30		
27	38	34	30	53	76	98	90	97	66	36	64	30		
28	41	27	47	64	89	98	95	101	68	50	61	34		
29	56		60	70	92	99	100	88	77	37	63	32		
30	57		75	77	94	98	97	93	76	44	66	31		
31	32		61		93		97	98		42		31		

DAILY MINIMUM TEMPERATURE 1918.

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	34	4	13	48	58	70	68	73	74	56	30	50		Lowest of the yea +4° on February 1st and on March 2nd. On 86 days the mi imum was 32° or be- low. The minimum on Jun 9th this year and i 1977 the lowest for the day since 1836. September 22 the lowest minimum on record for that day
2	31	15	4	54	62	67	72	69	77	57	39	53		
3	25	20	30	55	67	70	74	69	78	52	48	53		
4	24	14	31	41	62	63	74	73	77	57	42	48		
5	23	8	25	38	61	68	77	68	69	63	39	45		
6	19	7	16	47	53	70	72	77	73	65	40	51		
7	19	12	23	40	48	52	70	75	75	67	48	23		
8	15	17	39	40	54	49	71	80	71	65	34	22		
9	21	25	43	47	52	48	70	78	67	62	28	25		
10	24	32	36	43	42	49	67	75	63	64	28	32		
11	14	21	36	39	45	53	67	72	67	47	26	33		
12	7	12	39	38	49	57	67	78	60	50	43	36		
13	18	10	50	38	58	60	70	74	53	54	57	39		
14	17	25	35	41	69	62	75	75	53	58	45	41		
15	33	36	24	40	67	69	76	77	56	58	42	39		
16	49	32	23	49	55	71	76	77	64	59	41	34		
17	54	41	27	54	56	73	78	77	62	46	38	40		
18	34	41	43	61	59	74	78	75	61	43	51	32		
19	34	50	43	53	55	74	65	70	62	41	61	32		
20	20	38	38	47	60	74	68	71	49	32	61	36		
21	13	38	26	45	56	74	64	74	44	30	60	29		
22	25	26	22	60	54	67	64	69	40	36	51	28		
23	32	20	40	62	52	69	69	61	48	35	43	32		
24	29	12	44	55	48	70	67	64	58	42	39	33		
25	30	21	34	46	59	75	64	65	51	45	45	29		
26	35	34	25	44	58	73	71	68	50	36	46	28		
27	23	25	24	46	52	78	69	71	47	32	54	28		
28	27	22	24	42	59	79	74	77	57	32	55	29		
29	27		37	46	67	79	77	66	60	27	56	29		
30	32		49	55	76	78	77	68	60	30	52	29		
31	8		49		74		74	71		28		29		
	26	24	32	47	58	67	71^1	72^2	60^8	47^4	44^7	35		Mean Monthly

DAILY MEAN TEMPERATURE 1918:

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	44	10	22	58	70	82	76	82	86	66	38	54		
2	36	20	18	68	72	78	80	82	88	67	49	56		
3	32	25	43	62	74	78	81	84	90	65	56	56		
4	30	22	37	47	68	74	81	84	88	68	50	50		
5	27	12	33	50	70	78	86	80	81	70	47	49		
6	24	16	23	54	60	82	78	90	82	74	54	56		
7	25	20	33	44	58	64	78	88	82	70	58	36		
8	20	26	53	43	64	60	81	90	81	70	41	28		
9	24	30	53	56	64	59	82	86	75	70	35	34		
10	31	35	41	50	50	62	76	82	76	73	32	40		
11	27	28	42	42	55	66	77	81	78	55	36	42		
12	14	16	50	40	62	70	77	88	64	62	58	46		
13	28	20	55	44	72	72	82	81	62	66	63	48		
14	28	37	51	53	78	76	84	86	62	67	50	48		
15	42	45	27	52	74	82	80	88	62	67	46	42		
16	54	44	31	59	62	84	87	88	68	66	44	41		
17	56	48	43	69	66	86	89	87	71	54	46	44		
18	46	54	53	71	66	86	90	83	66	49	60	38		
19	48	59	56	60	66	86	76	79	69	46	67	38		
20	38	43	46	54	73	84	76	82	57	36	67	42		
21	22	47	31	60	67	86	73	84	50	36	68	34		
22	29	33	32	72	57	76	74	76	50	41	62	32		
23	39	23	58	70	56	78	82	72	63	42	48	34		
24	35	20	51	65	62	78	76	74	68	52	46	34		
25	44	29	38	50	67	82	74	75	63	55	48	31		
26	46	44	29	52	67	83	81	82	53	46	52	29		
27	30	30	28	50	64	88	80	84	56	34	59	29		
28	34	24	37	53	74	88	84	89	62	41	58	32		
29	42		51	58	80	89	88	77	68	32	60	30		
30	44		70	66	85	88	87	80	68	37	59	30		
31	20		56		84		86	84		35		30		
	34	30^3	41^4	55^7	67^3	78	80^7	82^8	69^6	55^2	51^9	41^8		**Mean Monthly**

DAILY SUNSHINE 1918.

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	55	50	59	100	100	76	9	100	94	94	85	30		Percentage of the possible sunshine.
2	00	00	100	86	94	91	35	100	95	100	54	13		
3	93	16	00	10	47	70	74	100	80	100	14	00		
4	45	60	11	6	36	85	71	77	100	62	94	00		
5	00	15	40	90	37	54	96	58	98	20	77	00		
6	00	67	100	100	67	83	85	80	87	45	95	64		
7	00	100	6	15	100	47	50	63	57	7	13	61		
8	8	100	100	00	100	17	50	98	17	26	23	100		
9	00	00	54	7	43	100	78	100	58	42	92	100		
10	00	00	00	61	9	100	100	66	100	58	80	96		
11	00	75	50	00	82	100	75	39	52	100	68	70		
12	90	100	29	6	68	100	97	50	00	100	52	98		
13	90	100	00	20	100	100	77	14	66	100	14	60		
14	84	100	80	100	100	100	63	86	67	76	00	19		
15	15	96	00	100	50	80	03	75	00	70	00	00		
16	00	60	97	100	46	100	100	68	8	16	07	17		
7	00	87	98	100	50	100	100	60	16	00	42	00		
8	87	100	100	90	76	80	89	39	00	45	43	100		
9	35	75	62	99	70	96	66	9	52	00	08	97		
0	00	00	17	95	89	48	85	62	11	04	07	14		
1	74	00	60	100	22	60	100	68	86	100	76	31		
2	14	85	61	90	6	30	96	100	93	00	15	00		
3	6	00	18	80	00	30	60	84	89	31	40	00		
4	50	100	5	41	100	37	64	97	86	77	46	00		
5	98	1	00	23	21	49	76	97	27	100	00	00		
6	53	00	1	32	68	100	61	100	39	35	00	00		
7	82	00	70	72	100	82	59	74	73	00	15	00		
8	00	00	100	100	100	91	79	62	00	31	00	00		
9	90		60	100	85	55	92	100	75	00	00	00		
0	27		84	100	81	99	57	80	90	96	07	00		
1	70		91		95		88	76		100		00		
	37	50	50	64	65	75	72	73	57	53	36	31		Mean Monthly

DAILY TOTAL WIND MOVEMENT 1913.

Date.	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Remarks.
1	256	225	297	183	235	201	107	186	210	196	115	87		TOTALS
2	306	198	322	365	253	131	72	103	134	231	172	54		Jan 7685
3	340	179	220	319	309	141	204	104	76	118	140	56		Feb 6154
4	219	124	201	358	312	132	168	129	88	258	119	69		Mar 8835
5	154	205	271	125	267	230	236	124	134	205	118	163		Apr 6944
6	213	211	298	229	252	132	169	226	221	191	209	186		May 6445
7	217	248	196	289	115	230	94	176	166	83	285	454		Jun 4487
8	228	200	187	389	136	183	152	263	108	98	454	176		Jul 4986
9	287	121	219	255	163	173	205	230	170	180	398	94		Aug 4471
10	195	167	109	328	121	155	132	201	145	317	337	226		Sep 5040
11	232	300	158	266	198	104	260	91	114	200	204	102		Oct 6138
12	219	245	268	235	157	96	216	127	154	157	253	104		Nov 6254
13	254	173	328	198	237	143	227	165	147	144	181	80		Dec 4360
14	214	153	483	203	265	161	215	116	171	213	140	90		Total 71799
15	299	235	407	113	246	155	158	83	223	105	147	120		
16	310	123	280	82	163	140	157	119	237	127	130	66		
17	231	189	346	136	173	101	206	96	104	268	183	81		
18	259	266	376	156	130	104	193	62	85	152	228	94		
19	316	275	400	148	262	144	184	78	149	143	267	155		
20	347	209	218	204	305	142	172	94	316	402	227	171		
21	144	267	480	311	272	182	94	122	274	223	330	169		
22	244	452	282	319	244	150	85	245	142	196	267	118		
23	177	200	360	431	179	156	201	86	338	179	165	182		
24	121	174	232	297	106	210	124	78	238	144	113	116		
25	145	289	245	91	170	250	186	129	204	142	214	346		
26	261	232	338	136	329	173	179	156	144	266	102	153		
27	249	297	289	221	186	89	130	103	95	327	107	186		
28	228	198	236	238	160	82	86	220	181	192	183	106		
29	270		250	103	203	72	138	185	105	340	224	140		
30	332		210	216	161	125	112	113	167	228	242	113		
31	418		329		136		122	261		113		103		
	10	9	11^{9}	9^{6}	8^{6}	6^{2}	6^{7}	6	7	8	8^{7}	5^{9}		Mean hourly

MEAN HOURLY TEMPERATURE °F

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	M	1	2	3	4	5	6	7	8	9	10	11	Midt	Mean
Jan.	33	33	32	31	31	31	31	31	31	33	34	36	37	37	38	38	37	37	35	35	34	33	33	32	34
Feb.	28	27	27	26	26	26	25	26	27	29	30	32	34	35	35	36	35	34	33	32	31	30	30	30	30
Mar.	39	38	38	37	36	36	35	37	38	40	42	44	45	46	47	47	47	46	44	44	43	42	41	41	41
Apr.	53	52	51	51	50	49	50	51	54	56	58	60	61	62	63	63	62	61	59	58	57	56	54	54	56
May.	64	63	62	61	59	59	61	62	64	67	69	71	73	74	75	76	75	74	72	71	69	68	67	66	68
Jun.	73	72	71	69	68	69	71	73	77	80	82	84	86	87	87	87	85	84	82	81	79	77	76	74	78
Jul.	76	75	74	73	72	73	74	77	79	81	84	85	86	87	88	89	88	86	85	83	81	79	78	77	80
Aug.	77	76	75	74	73	74	75	77	80	83	86	88	90	91	92	91	90	88	86	85	83	81	80	78	82
Sep.	66	65	64	63	63	62	63	64	66	67	71	73	75	76	77	77	76	74	72	71	70	69	68	66	70
Oct.	53	52	51	50	49	47	49	50	52	54	56	58	59	61	62	62	60	59	57	56	55	54	54	53	55
Nov.	49	48	48	48	47	47	47	48	50	52	55	56	57	57	58	57	56	55	54	53	52	51	50	50	52
Dec.	38	38	38	37	37	37	37	37	38	39	40	41	42	43	44	43	42	42	41	40	40	39	38	38	40
	54	53^{2}	52^{6}	51^{7}	50^{9}	50^{8}	51^{5}	52^{7}	54^{6}	56^{7}	58^{9}	60^{6}	62	63	63^{8}	63^{8}	62^{7}	61^{6}	60	59	57^{8}	56^{6}	55^{7}	54^{9}	57^{1}

MEAN HOURLY WIND VELOCITY 1913.

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	M	1	2	3	4	5	6	7	8	3	10	11	Midt	Mean
Jan.	9	8^{5}	9	9	9	9	9^{2}	9^{3}	10^{1}	11	11^{5}	11^{5}	11^{4}	11^{8}	11^{9}	11^{2}	10^{5}	10^{8}	11^{2}	11^{8}	11^{4}	10^{5}	10	9^{5}	10^{3}
Feb.	8^{6}	8^{4}	8^{3}	8^{4}	8^{3}	8^{7}	8^{8}	8^{5}	9	9^{8}	9^{6}	10^{7}	10^{5}	10^{6}	10^{5}	10^{9}	10^{1}	9^{4}	8^{7}	8^{7}	8^{7}	8^{7}	8	8	9
Mar.	11	11	11	10	9^{8}	10^{5}	10^{9}	11^{4}	12	12^{5}	12^{5}	13	13^{2}	13^{5}	13^{5}	13	13^{2}	13^{2}	12^{6}	11^{6}	12	11^{5}	11	10^{4}	11^{8}
Apr.	8	8^{6}	8^{5}	8^{5}	8	8^{1}	8^{8}	9^{5}	10	10^{5}	10^{1}	11^{3}	11^{5}	11^{6}	11^{9}	11^{7}	11^{8}	11^{1}	9^{2}	8^{7}	8^{9}	9	7^{6}	8^{2}	9^{6}
May.	6^{9}	7	7	6^{5}	6^{4}	6^{5}	7^{4}	8^{3}	9^{4}	9^{2}	9^{6}	10^{7}	10^{4}	10^{9}	11	11^{8}	11	10^{6}	8^{8}	8	7^{9}	8^{1}	7^{5}	7	8^{6}
Jun.	5^{2}	4^{9}	4^{8}	4^{4}	4^{6}	4^{8}	5^{2}	6^{2}	6^{6}	6^{7}	6^{6}	7^{3}	7^{3}	7^{2}	7^{8}	8^{5}	8^{3}	7^{6}	6^{9}	6	5^{7}	5^{8}	5^{9}	5^{3}	6^{2}
Jul.	5^{6}	5^{2}	5	4^{3}	5	5^{2}	5^{4}	6^{3}	6^{5}	7^{3}	7^{9}	8^{9}	8^{4}	8^{6}	8^{5}	8^{2}	8^{2}	8	6^{9}	6^{4}	6	5^{8}	6^{1}	5^{7}	6^{7}
Aug.	4^{8}	4^{1}	4^{5}	4^{5}	4^{2}	4^{7}	4^{9}	5^{1}	6	6^{4}	6^{8}	7^{5}	7^{1}	7^{5}	8	8	7^{6}	7^{8}	6^{7}	6^{4}	6	5^{4}	5^{1}	4^{9}	6
Sep.	6^{8}	5^{8}	6	5^{9}	5^{8}	5^{7}	5^{6}	6^{2}	7^{2}	7^{6}	8	7^{9}	8	8^{4}	9^{4}	9^{1}	8^{4}	7^{6}	6^{5}	6^{1}	6^{5}	6^{5}	6^{6}	6^{6}	7
Oct.	7^{6}	7^{3}	7^{4}	7	7	7^{2}	7^{3}	8	8^{3}	9	9^{6}	9^{5}	9^{6}	10	9^{6}	10	9^{4}	9	8^{1}	8^{1}	8	7^{4}	6^{6}	7^{4}	8^{2}
Nov.	8^{2}	8^{2}	8^{4}	8^{2}	8^{1}	7^{7}	8^{1}	8	8^{9}	9	8^{8}	9^{4}	9^{5}	9^{2}	9^{4}	9^{8}	9^{1}	9	9	8^{6}	8^{5}	8^{7}	8^{8}	8^{5}	8^{6}
Dec.	5^{1}	5	5^{1}	5^{7}	5^{6}	6^{3}	6^{2}	6^{6}	6^{2}	6^{6}	6^{5}	7	7	6^{8}	6^{8}	6^{3}	5^{9}	5^{5}	5^{1}	5^{2}	5^{1}	5^{3}	5	5^{3}	5^{9}
	86^{8}	84	85^{1}	82^{9}	81^{7}	84^{4}	87^{3}	93^{4}	102^{8}	105^{3}	107^{7}	114^{7}	113^{9}	116^{3}	118^{4}	118	112^{9}	109^{4}	99^{7}	95^{8}	94^{7}	92^{4}	87^{1}	86^{8}	97^{8}
	7^{2}	7	7^{1}	6^{9}	6^{8}	7	7^{3}	7^{8}	8^{3}	8^{8}	8^{9}	9^{5}	9^{5}	9^{7}	9^{8}	9^{8}	9^{4}	9^{1}	8^{3}	7^{9}	7^{8}	7^{7}	7^{3}	7^{2}	8^{1}

WIND DIRECTION, NUMBER OF TIMES OBSERVED, 1918.

	N	NE	E	SE	S	SW	W	NW	Calm	Prev. Dir.	☈.	Total Mil.	Mean Hourly Velocity.
January	5	0	2	19	8	3	9	16	0	SE	9	7685	10.3
February	13	3	1	16	1	2	11	9	0	SE	3	6154	9
March	8	2	1	23	4	4	9	10	0	SE	17	8835	11.8
April	13	4	7	18	4	1	8	5	0	SE	9	6944	9.6
May	10	3	3	25	6	4	5	6	0	SE	4	6445	8.6
June	8	3	9	14	6	4	15	1	0	W	3	4487	6.2
July	6	6	5	12	9	11	8	4	1	S	4	4986	6.7
August	12	3	7	18	10	2	3	5	2	SE	4	4471	6.
September	9	5	12	20	3	1	3	6	1	SE	3	5040	7.
October	13	1	0	21	2	1	11	12	1	SE	2	6138	8.
November	8	1	0	28	9	0	7	6	1	SE	4	6254	8.7
December	6	2	10	11	6	2	11	11	3	SE	1	4360	5.9
Total	111	33	57	225	68	35	100	91	9	SE	63	71799	8.1

TABLE OF ABREVIATIONS AND SIGNS USED IN METEOROLOGY.

○	Clear Days.	◓	Lunar Corona
⦶	Partly Cloudy Days	▲	Hail
●	Cloudy Days	△	Sleet.
⊕	Solar Halo	∞	Haze
◡	Lunar Halo	⌓	Dew
☈	Thunderstorm	⊓	Frost
◠	Rainbow.	≡	Fog
↗	Maximum Wind Velocity per hour, 30miles or more	✱	Days with snow.

St.	Stratus	Nb.	Nimbus	Ci.-St.	Cirro-Stratus
Ci.	Cirrus	A.-St.	Alto-Stratus	Ci.-Cu.	Cirro-Cumulus
Cu.	Cumulus	A.-Cu.	Alto-Cumulus	St.-Cu.	Strato-Cumulus
Fr. Nb.	Fracto-nimbus.	Fr.-Cu.	Fracto-Cumulus	Cu.-Nb.	Cumulus-Nimbus.
		Fr.-Cs.	Fracto-Stratus.		

MISCELLANEOUS PHENOMENA. 1913.

	○	⦶	●	⊕	◡	☈	▲	△	⊓	≡	◠	⌓	✱	Remarks.
January	9	5	17	1	2	1	0	4	4	7	0	0	2	
February	12	4	12	0	2	1	0	3	4	4	0	0	6	
March	12	6	13	1	0	5	2	0	1	3	0	0	6	
April.	18	2	10	0	1	4	0	0	1	3	0	1	0	
May	16	9	6	2	1	4	0	0	0	2	0	3	0	
June	19	7	4	0	0	8	1	0	0	1	0	0	0	
July	17	11	3	0	1	9	1	0	0	2	1	0	0	
August	18	10	3	0	0	8	0	0	0	0	1	0	0	
September	13	7	10	0	1	4	0	0	0	3	0	3	0	
October	12	6	13	0	2	3	2	1	1	3	0	1	3	
November	6	8	16	0	0	4	0	1	1	5	0	0	0	
December	7	3	21	0	2	0	0	0	4	4	0	2	1	
Total	159	78	128	4	12	51	6	9	16	37	2	10	18	

Acknowledgments.

Our thanks are hereby tendered to the many kind friends who have supported the Geophysical Observatory during the past year, as well as to the following, whose contributions and exchanges have enriched the Observatory Library.

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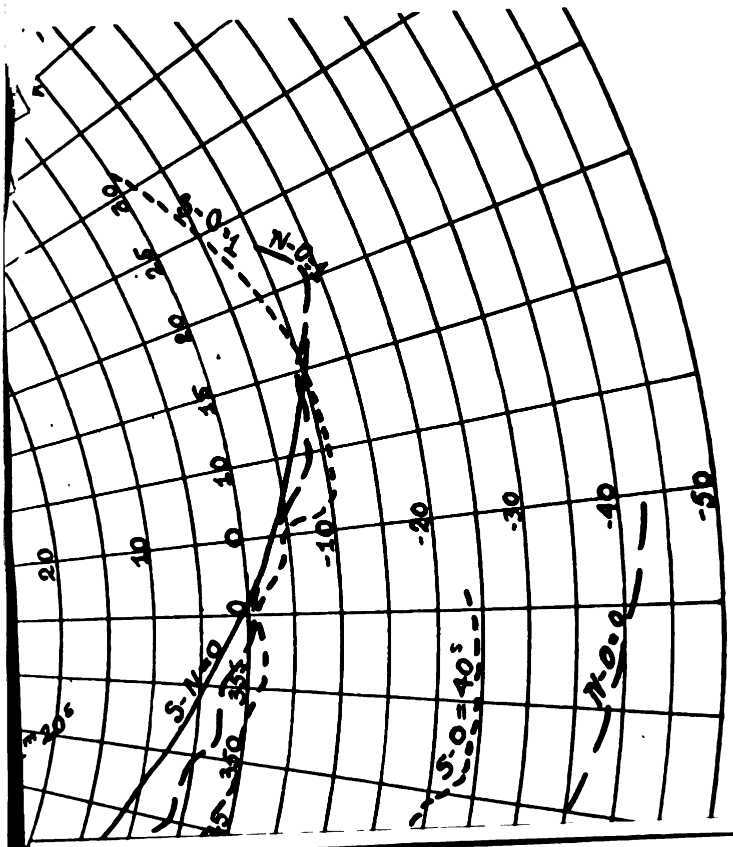

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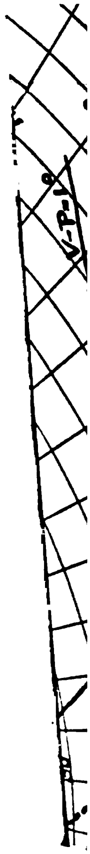
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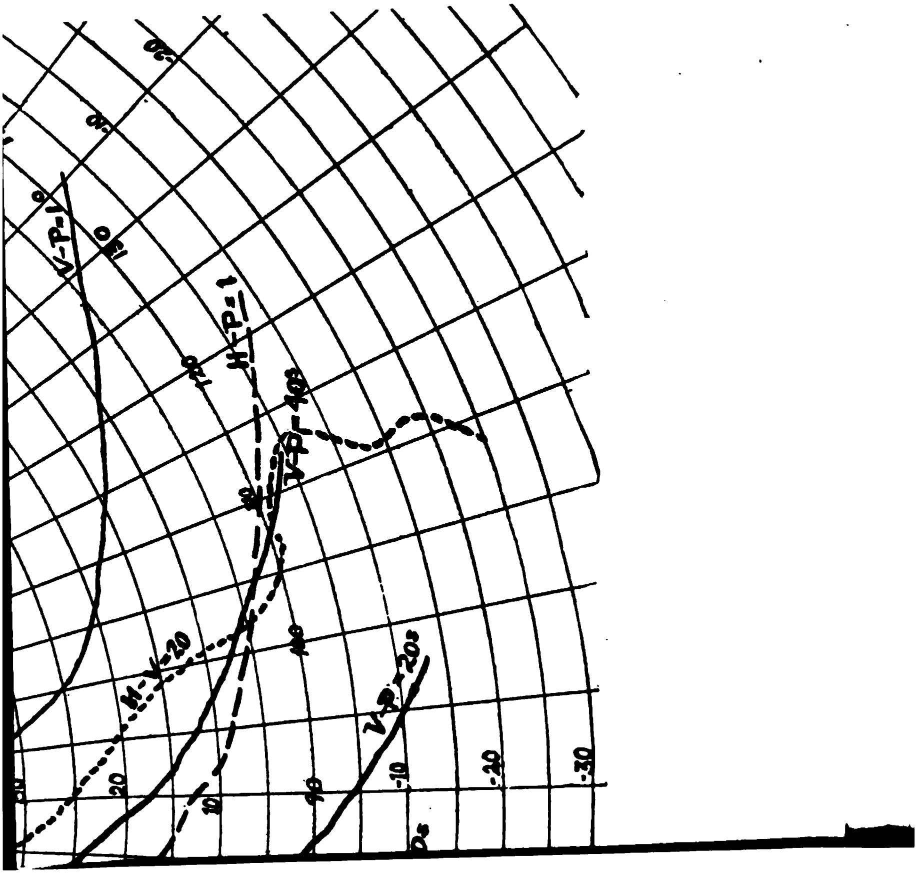

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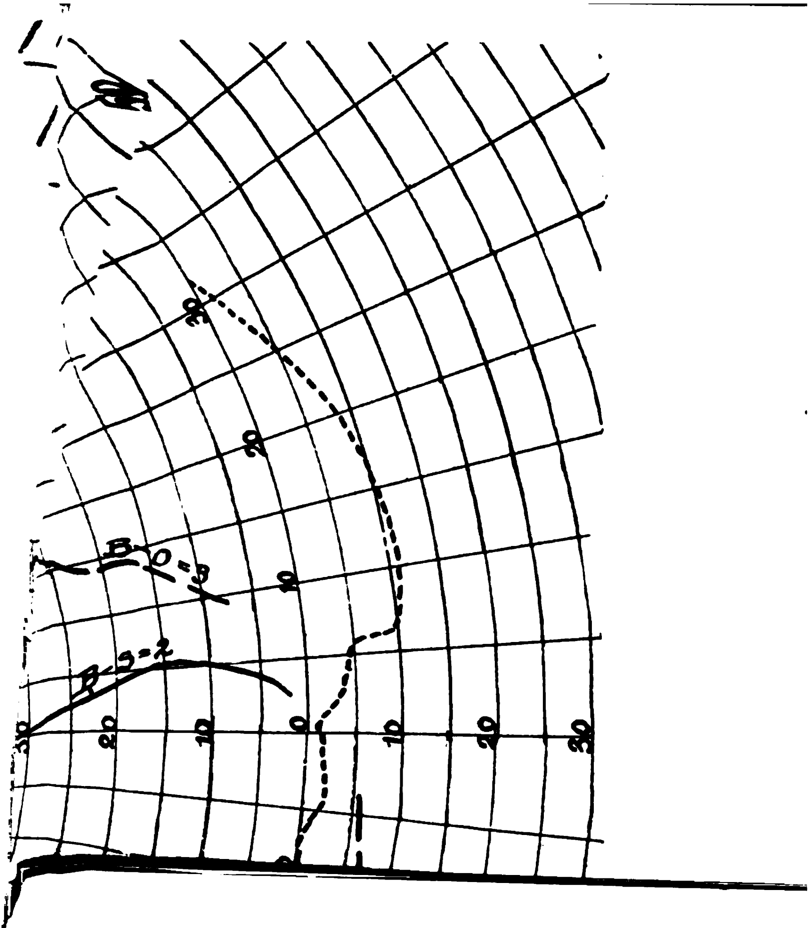
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